Institut National de la Recherche Scientifique

Eau - Terre - Environnement

Summary

Evaluation of the Deep Geothermal Potential of Baker Lake, Nunavut, Canada

01.2024

For Nunavut Planning Commission

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1 Non-technical Summary

1.1 Project Title:

Evaluation of the Deep Geothermal Potential of Baker Lake, Nunavut, Canada

1.2 Lead Researchers and Affiliation:

This research project, carried out by the Institut National de la Recherche Scientifique, will be led by Pr. Jasmin Raymond, as research director, brings his expertise as holder of the Chaire de recherche INQ sur le potentiel géothermique du Nord. Dr. Mafalda Miranda, who recently presented a thesis evaluating the geothermal potential of the community of Kuujjuaq, brings direct experience in similar projects, reinforcing the relevance of her contributions to our team. Ysaline Bacon, a master's student, will write her dissertation on this project.

1.3 Research Questions:

Switching to renewable, locally produced, and environmentally friendly energy sources such as geothermal energy could bring many socio-economic advantages to diesel-dependent communities such as Baker Lake. Therefore, evaluating the deep geothermal potential of the community of Baker Lake is of great interest. If techno-economic viable, geothermal resources could provide them with an economical, local and environmentally friendly alternative for heating. It's important to note that our choice to explore the geothermal potential of Barker Lake is driven by Qulliq Energy Corporation (QEC)'s desire for more information in this regard. Our intention is to provide additional insights to complement the geothermal exploration project undertaken by Respec on behalf of QEC. This project therefore aims at answering the following research questions:

1) Are the deep geothermal resources beneath Baker Lake capable of meeting the community's heating and electricity demand?

2) Can the deep geothermal resources in Baker Lake be obtained at a competitive cost? Fieldwork, laboratory analyses, numerical modeling and life-cycle cost analysis are envisioned to answer these questions. Fieldwork will help gaining insights into the main lithological units and fluid pathways network. Laboratory analyses will help define the thermophysical properties of the lithological units. The data collected in the field and laboratory will then be used to inform numerical models, which will help address questions related

to the performance of the geothermal system. Finally, life-cycle cost analysis will help understanding if geothermal is a cost-competitive solution. These are affordable geothermal exploration tools for a first-order assessment of Baker Lake deep geothermal potential.

1.4 Research Objectives:

The primary objective of this research project is to provide a first-order assessment of the deep geothermal potential of Baker Lake. Through uncertainty quantification and parametric analysis, we will identify key parameters that need further gathering of information to de-risk future geothermal projects in Baker Lake.

Secondary research objectives include:

1) Study of the local geology, including lithology, fractures, and tectonic structure, from outcrops. The data collected will help gain insights into the main lithological units present in Baker Lake and into the geometry and connectivity of the natural fracture network. This objective is of particular interest to build conceptual models of the geology and flow circulation beneath Baker Lake.

2) Characterization of the thermophysical properties of rock samples representative of the main lithological units. This objective is key to develop models to evaluate the temperature and depth of the geothermal reservoir.

3) Assessment of the theoretical geothermal potential to estimate the amount of energy stored beneath Baker Lake and the amount of energy that could be recovered with a geothermal system. This objective will help assess the level of risk of producing heating and electricity from geothermal resources in Baker Lake.

4) Development of numerical models of geothermal systems. This objective will help to forecast the quantity of energy that could be produced and the best design to maximize the thermal energy extraction, keeping the system sustainable.

5) Analysis of the life-cycle cost of the geothermal system. This objective will inform about the economics of geothermal energy production in Baker Lake and will help understand if geothermal energy is a cost-effective solution. Additionally, this project aims to contribute to a growing thermo-hydro-mechanical properties database that includes data from several communities in northern Canada. The results of this research project could potentially promote geothermal development in remote northern regions. Through this project, we intend to uphold environmental and social values held by the Baker Lake community by providing access to sustainable energy independence.

1.5 Where, When, and Duration of Field Research:

Field research is scheduled for the summer of 2024 (between June 1, 2024, to September 30, 2024) and will be conducted within a limited area (less than 10 km) surrounding the Baker Lake community. The fieldwork is expected to span over three weeks.

1.6 Methods for Fieldwork:

Research methods will encompass fracture studies, geological mapping, and the collection of surface rock samples. Fracture data will be collected using linear scanline and rectangular window sampling methods. Linear scanline sampling involves laying a tape on an outcrop and measuring attributes (including orientation, length, aperture, intensity, fracture fill and spacing) of each fracture that intersects the tape. Rectangular window sampling utilizes a rectangle, which is placed on an outcrop and selected fracture attributes are measured within the area of the rectangle. Surface rock samples will be collected with the help of a geological hammer.

1.7 Environmental, Wildlife, and Societal Impacts:

Since no drilling activities are planned, we expect minimal environmental and societal impacts from our research. Our field research activities will be conducted quietly and with utmost respect for the environment. Despite the research's proximity to the community, there are no expected impacts on wildlife. Concerning the social impact, the community of Baker Lake has already been exposed to the works conducted by Respec in December 2022, which took the time to engage in dialogue with local residents. Based on this experience, we anticipate a positive response from the community towards our research efforts. Furthermore, it is important to note that we will be conducting follow-up activities with QEC. This collaboration is crucial as QEC could ultimately, in partnership with the community, utilize our research findings to advance towards the development of geothermal resources if such a desire is expressed by the community itself. This proactive approach underscores our commitment to transparent communication, community engagement, and potential collaboration for the benefit of Baker Lake and its residents.

1.8 Data Storage and Management:

The results obtained from the 2024 fieldwork will remain within our institution until their public release in spring 2025, in the English language.

1.9 Involvement of Nunavut Residents:

The Baker Lake community will be actively engaged in the research by sharing their expectations and limits. Their preferences for heating and energy sources will contribute to building a realistic model for assessing the potential and feasibility of installing a geothermal heating system within the community.

1.10 Communication of Research Results in Nunavut:

Research findings will be shared with the Baker Lake community through a non-technical report presenting the results of our research. Communication with our research team will remain open throughout the project, and we welcome any future collaboration. This project aligns with environmentally responsible practices and the specific needs of the community, striving to provide a sustainable energy solution while preserving local values.

2 Technical Summary

2.1 Objectifs

This project aims to conduct a comprehensive assessment of the geothermal potential in the Baker Lake community, Nunavut, Canada, focusing on both short-term and long-term objectives.
In the short term, the field objectives are as follows:

1. Conduct a preliminary mapping of various lithologies near the community and obtain subsurface samples without drilling.

2. Create a more detailed structural geological map, emphasizing the study of folds and fractures to determine the current and past stresses in the system.

3. Explore fractures using visual quantification methods initially, with the option of generating fractures if the results are insufficient.

In the longer term, the overarching goals of the project include:

1. Assess the geothermal potential of the Baker Lake community, taking into account the Archean geological context and the presence of permafrost.

2. Determine the geothermal gradient in the region, as well as the conductivity and resistivity of subsurface rocks, extrapolating these properties to depth.

3. Model the geothermal potential by considering the installation of an Enhanced Geothermal System (EGS) in a deep geothermal reservoir to extract hot water for community buildings.

4. Study the feasibility of such an installation by calculating the levelized cost of energy, the lifespan of the facility, and assessing possible trade-offs with community needs.

2.2 Context and Justification:

This project is part of an evaluation of geothermal potential in the Canadian Arctic, where case studies conducted in other communities with similar geological characteristics have yielded positive results. The Baker Lake community heavily relies on external sources of

energy, making the exploration of alternative energy sources essential to increase energy independence.

Geothermal research in Nunavut and the Baker Lake community is of great importance for several reasons. Firstly, it provides an opportunity to reduce almost total dependence on diesel for energy production, which could lower fuel import costs. Geothermal energy can be used for home heating, offering thermal comfort while reducing energy costs. Finally, this transition to a clean energy source could stimulate local economic development by creating jobs and reducing high energy costs associated with the region's geographical remoteness and extreme weather conditions.

2.3 Progress to Date:

Qulliq Energy Corporation (QEC) has been interested in assessing the deep geothermal energy potential of Nunavut. The company has awarded contracts to RESPEC Consulting Inc. to investigate the feasibility of geothermal energy in the territory. The first phase aims at collecting existing data, identifying data gaps, and conducting an assessment of geothermal resources based on the available data. Data collection involves gathering underground thermal information from publicly available government datasets, research journals, and samples from perennial sources.

The data analysis reveals a significant lack of data in the Nunavut territory, with only one applicable underground thermal data point identified in the Canadian Shield region. The geothermal favorability map generally indicates low geothermal favorability for Nunavut due to the absence of data over a large area. However, certain areas, such as the community of Baker Lake, show a moderate development potential, suggesting initial targets for Enhanced Geothermal Systems (EGS). The study recommends the analysis of Temperature Gradient (TG) wells to verify the underground thermal properties of this community.

Afterward, Phase II involved the drilling of a 500 m deep borehole within QEC property nearby the diesel power plant of Baker Lake. The total length of the borehole was cored, and temperature sensors were installed in the well. Our team at INRS worked with Respect Inc. and QEC to carry out a preliminary evaluation of the geothermal gradient and terrestrial heat flow. This study also involved a characterization of the thermal conductivity, thermal diffusivity and volumetric heat capacity of rock samples, thanks to the cores obtained by Respect Inc. in December 2022. Additionally, petrophysical, chemical and rock mechanics analyses (ICP-MS, XRD, Nano-Permeability, Geomechanics) are ongoing in our partner laboratories.

2.4 Methodology:

Short-run Methodology : Field work

Structural Study of Baker Lake: Prior to commencing our field expedition, a preliminary structural analysis will be conducted using satellite images from the ArcticDEM database, complemented by an in-depth literature review focusing on the Meadowbank mine and existing geological mapping. This preliminary approach aims to identify areas of interest for our field study.

Preliminary Mapping and Lithology Sampling: On-site, a detailed analysis of lithology will be conducted based on literature indicating the presence of Archean gneissic soils. The objective is to identify areas with the highest geothermal potential, examining parameters such as quartz content and porosity.

Structural Geological Mapping: A detailed structural geological map will be established, emphasizing the study of folds and fractures. This mapping will be carried out through direct observation in the field to understand current and past constraints on the system.

Fracture Exploration: Given the complexity of the Canadian Shield, we anticipate a network of heterogeneous faults. The augmented circular line method will be employed in conjunction with surface sampling to collect data on fractures, including orientation, length, aperture, spatial distribution, and intensity. The circular method developed by Mauldon et al. (2001) will be applied to calculate fracture intensity. These data will be compiled on a comprehensive map for thorough analysis.

Long-run analysis : Laboratory analysis

Thermophysical analysis: Samples will undergo analysis for radioisotopes 238U, 232T, and 40K to estimate radiogenic heat production. This analysis will be conducted using gamma-ray spectrometry, with results compared to those obtained by ICP-OES/MS for validation. The thermal conductivity analysis will be performed on all samples using the infrared thermal conductivity scanner (TCS) technique. These data will contribute to the modeling of geothermal aspects.

Laboratory analyses of rocks collected at the surface are detailed in the article by Miranda et al. (2020) titled "Thermophysical properties of surficial rocks: a tool to

characterize geothermal resources of remote northern regions" published in Geothermal Energy, 8(1), 4.

COMSOL Multiphysics Modeling: After completing chemical analyses, modeling on COMSOL Multiphysics will commence, integrating analysis results for an accurate representation of the geothermal reservoir. The modeling will evaluate the geothermal potential of the Inuit community, simulating the reservoir's response to the installation of an EGS system. Production and injection strategies will be adapted based on reservoir evolution, ensuring a sustainable and adaptive approach. This integrated methodology aims to provide an in-depth understanding of the geothermal system of Baker Lake. The detailed method is explained in the article by Zinsalo, Lamarche, and Raymond (2020) titled "Injection strategies in an enhanced geothermal system based on discrete fractures model," published in Applied Thermal Engineering, 169, 114812.

2.5 Data Management:

The data obtained during this fieldwork will be used to deduce the geothermal potential of the community. They will then be made public through a master's thesis publication. Subsequently, the data generated by this study will be added to the data already obtained by my work team in other communities, allowing the community, if desired, to use this data in the construction of a geothermal heating project.

2.6 Research Results:

The main research results will be communicated in spring 2025 through various means. This includes the publication of a detailed scientific article and the incorporation of results into a master's level university thesis. Additionally, a non-technical version of the results will be shared with residents of the Baker Lake community and other stakeholders to ensure effective communication of the project's findings.