Proceedings World Geothermal Congress 2026, Calgary, Canada, June 8—11, 2026

Geothermal Exploration Challenges in Canada

Alonso Torres, D.[1]*
Advection Geo, Suite 1800, 330 5th Avenue SW, Calgary, Aberta, Canada
Daniel@advectiongeo.ca

ABSTRACT

Exploration represents an essential initial step in the development of any natural resource, and a necessary activity for the continued economic growth of societies.

In geothermal energy, exploration ranges from field surveys of thermal springs to complex data-driven methodologies and multi-million-dollar drilling campaigns. Geological, geochemical, geophysical, remote sensing surveys, and exploratory drilling are tailored to specific geological settings. These activities are used to identify signs of geothermal activity, define the type and distribution of geothermal resources, and inform decision-making for capital investments and land-use planning. Innovative techniques in each of these fields continue to be developed, but their effectiveness is dependent on site-specific conditions. Policies that require the publication of geoscientific data while protecting competitive proprietary information, along with systems to maintain these databases over decades, are instrumental in leveraging the value of exploration investments.

Canada presents unique geological conditions that pose difficulties for the exploration of geothermal resources. Extensive glacial, lacustrine, fluvial, and volcanic deposits conceal the underlying bedrock, prevent and dilute the upward migration of deep fluids, and hamper signal quality in geophysical surveys. This stacking of aquifers and aquitards can also cause geothermal systems to go undetected during drilling. The northern climate, vegetation cover, wildlife, remoteness, limited infrastructure, and labour availability in much of Canada present further challenges and increase exploration costs and timelines. Historical geoscientific data focused on extractive industries, while abundant, frequently omitted areas and datasets relevant to geothermal resource exploration. In this environment, thoughtful planning is paramount to the success of geothermal exploration campaigns.

INTRODUCTION

The development of geothermal resources in Canada presents additional, untapped opportunities for building economic, decarbonized, local, long-lasting infrastructure for heat and electricity generation, providing an underexplored avenue for sustainable economic development.

Due to the subsurface nature of these resources, substantial data collection in the form of exploration needs to occur at the initial stages of evaluation and development. Exploration programs are used to acquire geoscientific information about the subsurface on both regional and prospect scales. Advances can be made during the evaluation stage by utilizing existing data from academic works and previous subsurface activities (i.e., oil and gas, mining). While helpful on a regional scale, these data are seldom available in prospective areas for geothermal energy, and frequently do not have the data types, quantity, and qualities to replace prospect-scale data collection, prompting the need for targeted surveys and studies to better understand geothermal resources.

Within Canada, the exploration for geothermal resources faces unique challenges related to its geological conditions, geography, and other factors. Some of these are shared between the Western Canada Sedimentary Basin (WCSB) and other regions, while others are specific to a geological setting. Understanding these factors and their impacts is crucial for the planning of successful exploration campaigns.

GEOLOGICAL AND GEOGRAPHIC CONDITIONS IN CANADA

Canada is the 2nd largest country by area in the world, with a population of just over 41 million people concentrated along the 49th parallel, and in major urban centres. Low population densities in most of the country result in limited infrastructure, labour, and service availability. This remoteness is combined with a cold northern climate with long snowy winters, and extensive boreal forest coverage, presenting logistical challenges for land-based activities.

Geological conditions across vary across the country, including cool to moderate temperature sedimentary basins in the eastern provinces and northern islands, the shield that covers much of the central and northern portions of the mainland, the WCSB and its foreland extensions further north, and the Canadian Cordillera to the west. This mountainous region includes 5 volcanic zones, some of which generated large volumes of lava blanketing the surface, as well as major crustal scale faults and variably deformed sedimentary basins. All of the geothermal surface manifestations in the country are located along the Cordillera. Hydrocarbon activities are extensive in selected basins such as the WCSB, and associated data is available. Mineral exploration activities are widespread throughout the Canadian Shield and the Cordillera, while water production is spread throughout the country and focused on shallow sources. The recent history of glaciation has resulted in the generation of a rugged topography in the Cordillera, as well as extensive glacial deposits at surface throughout the country.

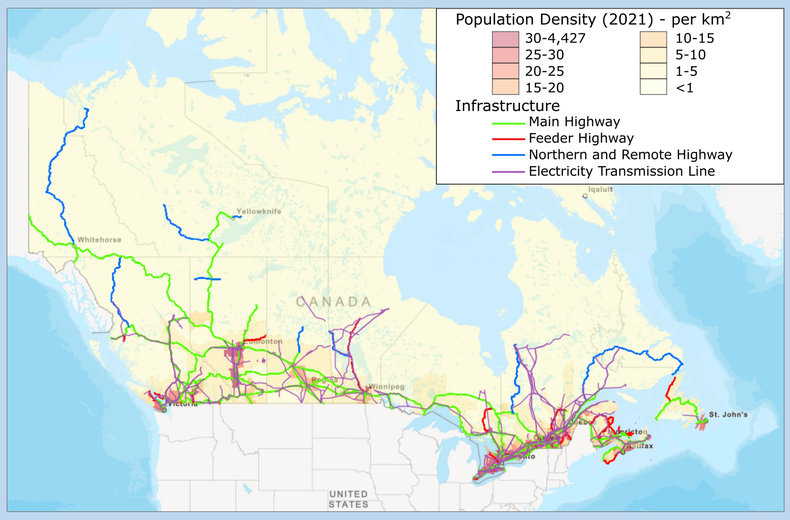


Figure 1. Infrastructure map of Canada.

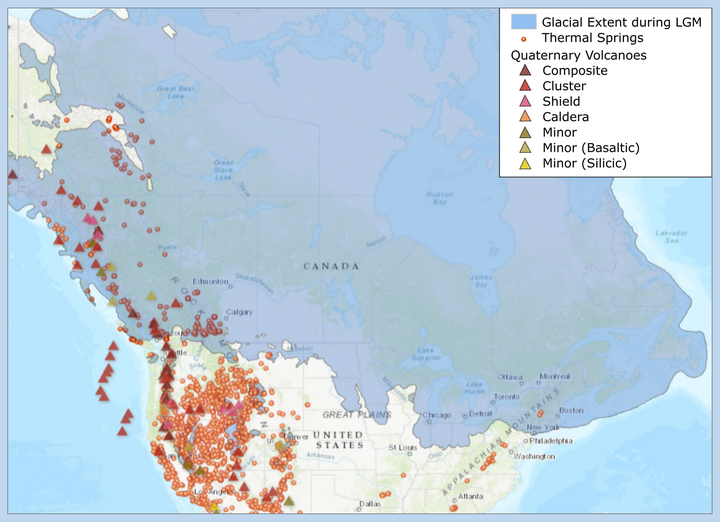


Figure 2. Glacial cover, thermal springs, and volcanoes in North America.

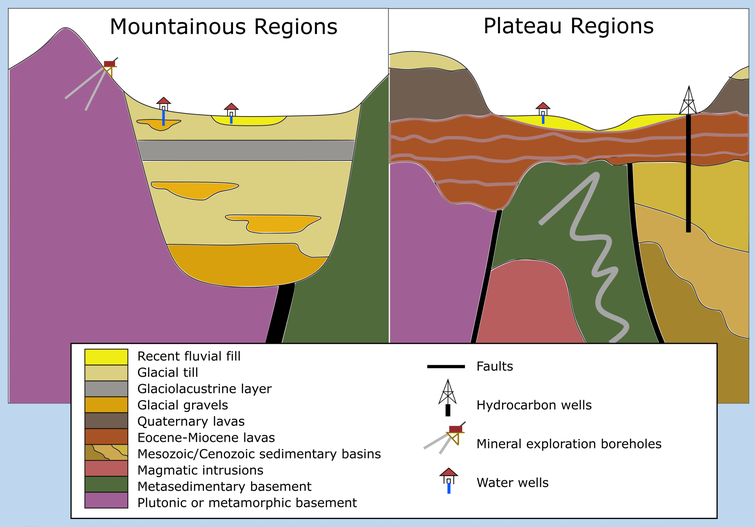


Figure 3. Schematic geological conditions in the Canadian Cordillera.

IMPACT ON EXPLORATION TECHNIQUES

The geological and geographic conditions in Canada present specific challenges for the successful execution of geothermal exploration activities, particularly in prospective areas for geothermal development for electricity generation in the Canadian Cordillera.

- The sparse populations, remoteness, and limited infrastructure across much of Canada results in additional contingency needs and logistical planning, while limiting the availability of services, and increasing travel and response times, all of which impose additional costs on exploration campaigns.
- Extensive vegetation cover in boreal forests and rainforests prevalent in mountainous and northern regions has a detrimental impact to geological mapping as it reduces outcrop exposures of bedrock and geothermal features (e.g., travertine, sinter), and hinders foot and vehicle access. Remote sensing surveys (e.g., multispectral, InSAR) are detrimentally affected by the low point density in vegetated regions, while airborne thermal scans are limited in their capacity to detect thermal anomalies below the forest canopy, and are restricted to waterbodies and clear areas.
- Cold weather throughout much of the year, often accompanied by deep snow and deep freeze temperatures, requires snow-clearing, heating, and additional safety measures for fieldwork and drilling, as well as limiting certain surveys to specific seasons, presenting a high potential for added costs, increased logistical complexity, and project delays. The presence of wildlife can similarly introduce risks to travel and field activities and require additional mitigation and management measures, with the consequent increase in cost and complexity.
- Subsurface data is sparse throughout much of the country, particularly in regions with no history of hydrocarbon production, and some of it is of vintage quality. Geophysical arrays, volcanological data, wells and boreholes, and bedrock mapping are limited in extent, density, or resolution, with notable exceptions of aeromagnetic and gravity surveys, and some of the datasets historically collected by industry and academia are not available, have low resolutions and inflexible formats, or present methodological limitations.
- Abundant well and borehole data in regions with a history of hydrocarbon production aid in the identification of geothermal properties, thanks to data-sharing policy requirements and reliable storage throughout the decades, but is biased towards petroliferous regions and formations, and testing is prioritized for attributes relevant to hydrocarbon exploration and production. Mineral exploration boreholes are not yet inventoried, and are similarly biased towards mineral prone regions, depths, and locations such as mountain tops and slopes, while most geothermal manifestations occur in the adjacent valleys. Tests and analyses of mining exploration boreholes seldom include factors beyond rock petrological and geochemical properties. Water well data is also available across much of the country, and is helpful in the investigation of overburden and bedrock aquifers. However, most water wells tap into shallow formations in alluvial fans, fluvial deposits, and glacial cover, and reports rarely contain descriptive geological information, physiochemical measurements or analyses, or well logs.
- Glacial, lacustrine, and fluvial overburden, as well as volcanic deposits, blanket large regions of the Cordillera, and present difficulties to geological mapping, geophysical surveys, and drilling. Bedrock exposure can be limited in areas peneplained by glaciation, or covered by volcanic flows of Cenozoic age, limiting geological mapping coverage. Gravity, magnetic, electromagnetic, and seismic surveys are often affected by the strong contrast in the physical properties of overburden, volcanic cover, and bedrock, which can have detrimental effects on data quality, interfere with signal penetration, and introduce uncertainties in the inversion, modelling, and interpretation of these datasets. Drilling activities can also be significantly affected by overburden and volcanic cover, as the stacking of vastly different hydrogeological formations introduces risks associated with artesian flows and kicks, internal flows within the well, and requires additional planning, contingencies, response equipment, casing strings, and rig size, all of which increase the complexity and costs of drilling campaigns. Lastly, another effect of the overburden on geothermal operations relates to the rheological properties of the shallow, unconsolidated, water-saturated, and weak formations, as well as permafrost, which can present geotechnical hazards and seasonal load restrictions on roads.