Mapping Technoeconomic Feasibility of Geothermal Resources in Alberta

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INTRODUCTION

Identifying favorable locations to place geothermal projects typically starts with evaluating the geothermal gradient in a region; however, the feasibility of a project also depends on ease and costs of drilling, proximity to customers, and practical factors such as proximity to existing infrastructure. The geothermal gradient in the Canadian province of Alberta was first mapped in the early 1990s. Since then, geothermal maps of the Western Canadian Sedimentary Basin (WCSB) have evolved with the integration of higher quality temperature data and improved spatial coverage from wells drilled across the province.

My research project uses geothermal gradient maps developed by Majorowicz (2018) to estimate depths to various temperatures of interest (40°C, 80°C, 120°C, 150°C), then uses publicly available data like the Alberta Government Modernized Royalty Framework to estimate drilling and well completion costs to the depths associated with those subsurface temperatures. These provincial drilling cost maps are combined with other data sets such as infrastructure, geologic structure maps, and reservoir stimulation costs to further characterize the costs associated with developing a geothermal project in an area. Potential sources of revenue (electricity, direct use heat, carbon credits, and lithium extraction from geofluids) are evaluated with a variable price and variable flow model to determine what conditions are required for a geothermal project in a region to result in a positive net present value (NPV).

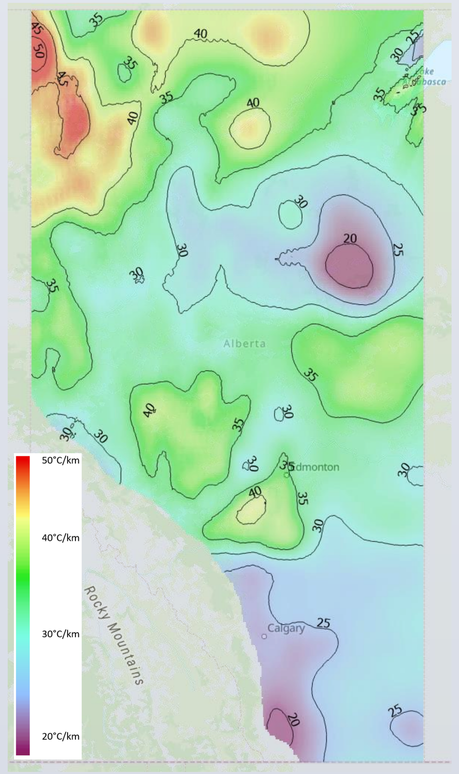
GOAL AND OBJECTIVE

Goal: mesh multiple variable-cost geospatial data sets together using a Geographic Information Systems (GIS) platform to produce an interactive picture illustrating the economic status of Alberta's geothermal energy prospects.

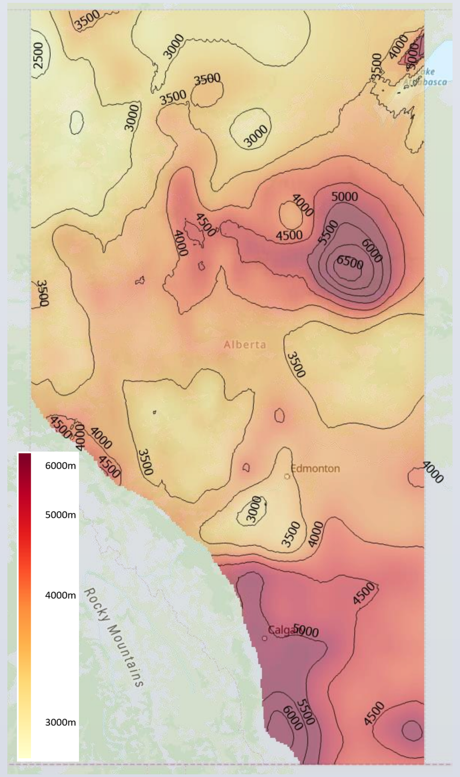
Alberta's geothermal gradients ranges from 20-50°C/km, and as such depth to usable resources varies; for example, depth to 120°C varies between 2.5 and 6km **(Maps A & B)**.

The commercial viability of the 120°C resources are dependent on the depth to Precambrian Basement, estimated drilling costs **(Map C)** and other factors such as proximity to infrastructure.

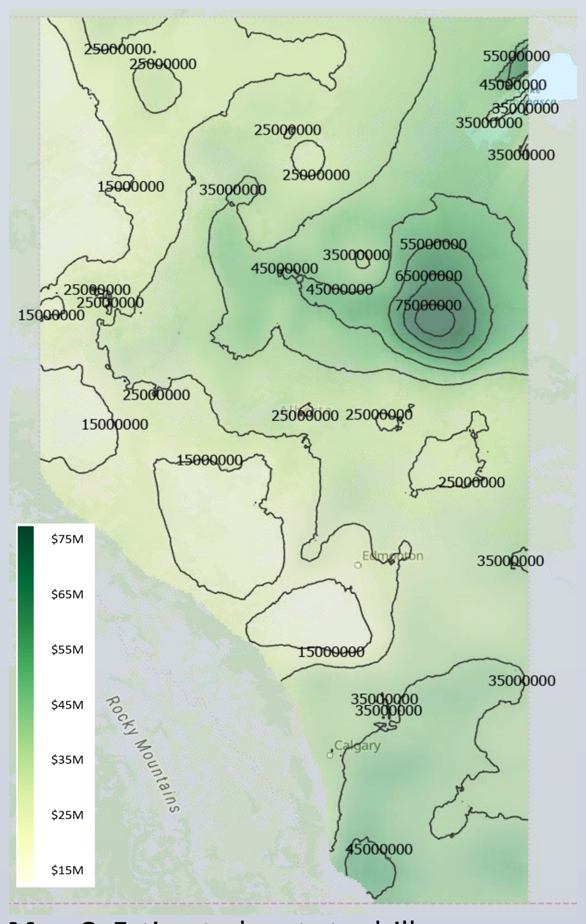
Objective: generate map sets that provide a picture of the viability of geothermal energy in the WCSB under varying technoeconomic scenarios.



Map A: Geothermal Gradient (°C/km) map of Alberta. From Majorowicz (2018).



Map B: Estimated depths (m) to achieve subsurface temperatures of 120°C are between 2.5 & 6km.

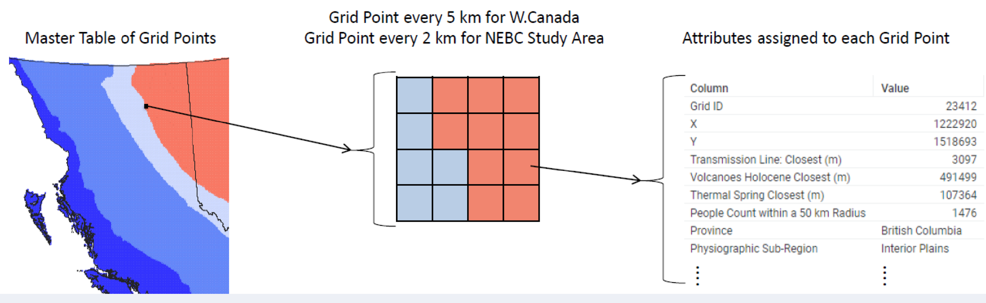


Map C: Estimated costs to drill a doublet (2 wells) to reach subsurface temperatures of 120°C

This research project's goal & objective align with UN Sustainable Development Goals #7, #9, & #11. (The United Nations, n.d.)

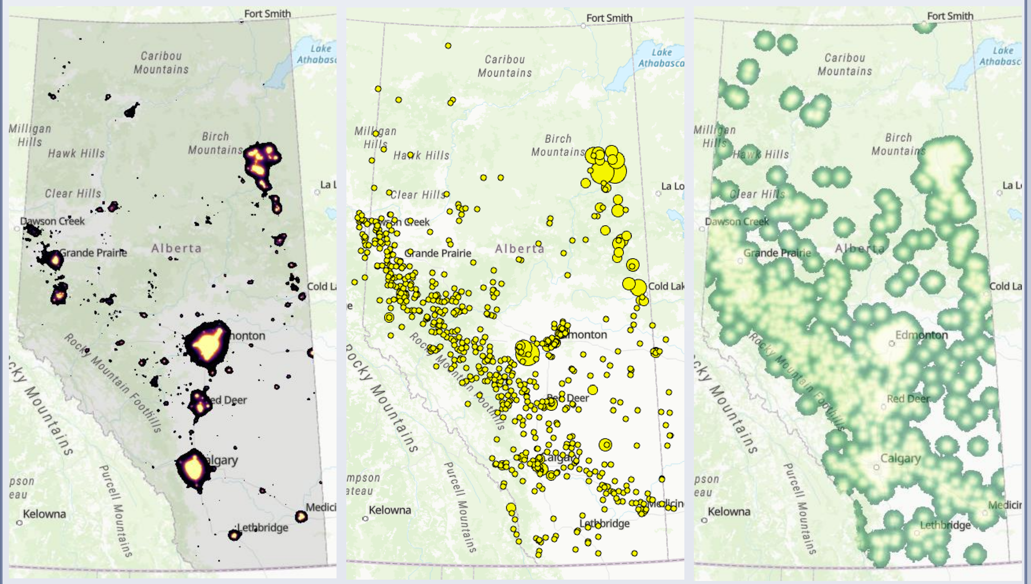
MATERIALS AND METHODS

A model of the province of Alberta was developed using a 5km x 5km grid. GIS-compatible layer files were used to assign key attributes to each grid cell following a similar approach as Harms & Kalmanovitch (2021).



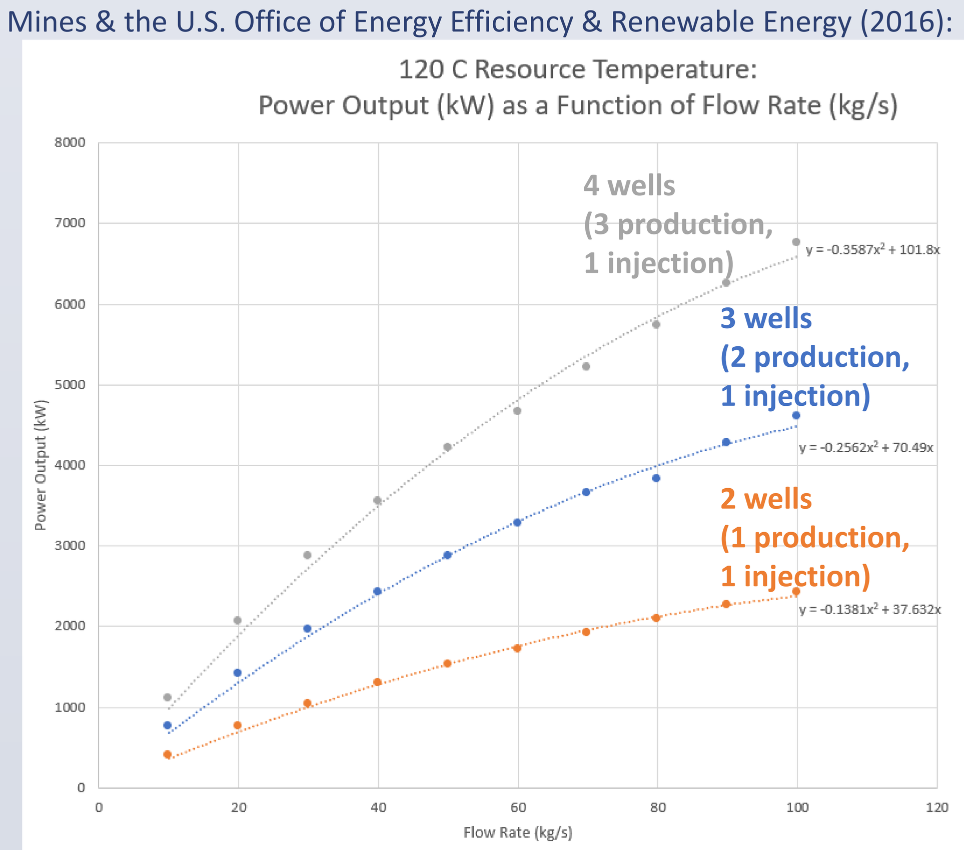
Source: (Harms & Kalmanovitch, 2021)

One key layer was a map of customers to offtake heat from a geothermal project. The map of potential customers who were assumed to be able to use heat was developed from light pollution data (Falchi, 2016) and GHG emitting facilities (Government of Canada, 2022) **(Maps D-F)**. Since transporting high-temperature fluids long distances is not efficient, the maximum distance to a customer was limited to 20km.

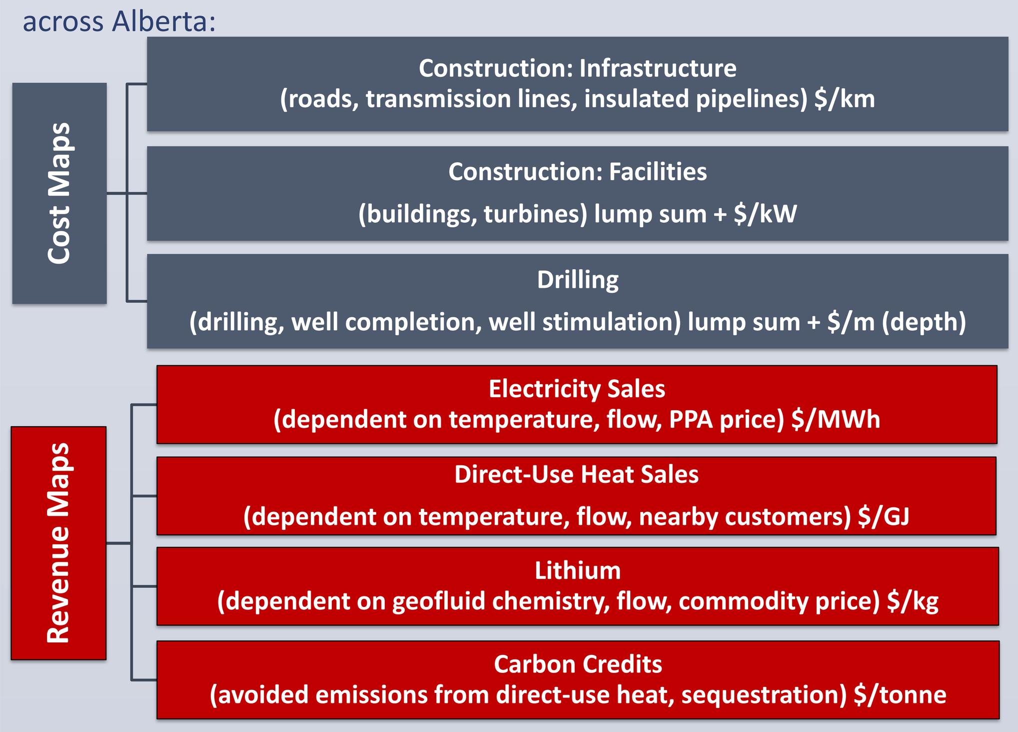


Map D: Light pollution data. From Falchi et al. (2016) **Map E:** GHG emitting facilities. From Government of Canada, (2022) **Map F:** Direct-use heat customer map.

Net power output for the 120°C and 150°C resource temperatures was estimated as a function of flow rate using the GETEM tool developed by Mines & the U.S. Office of Energy Efficiency & Renewable Energy (2016):



Attributes for each grid cell were used to estimate costs and revenues across Alberta:



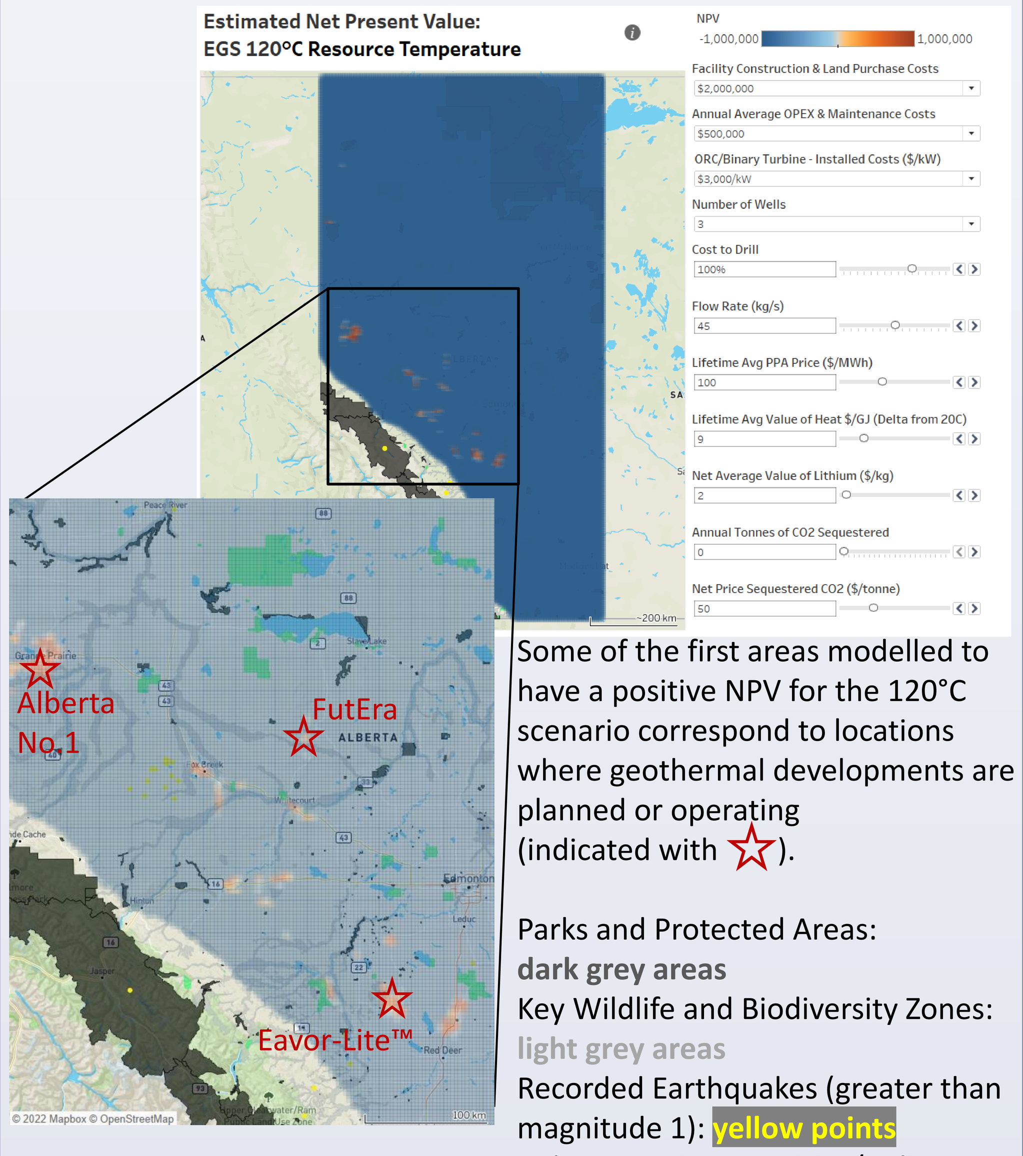
Costs and revenue maps were used to complete a Net Present Value Calculation:

$$NPV = \sum_{n=1}^{Project\ Lifetime} \frac{Net\ Annual\ Revenues}{(1 + Discount\ Rate)^n} - \sum Project\ Costs$$

A project lifetime of 35 years and an annual discount rate of 5% was used.

RESULTS

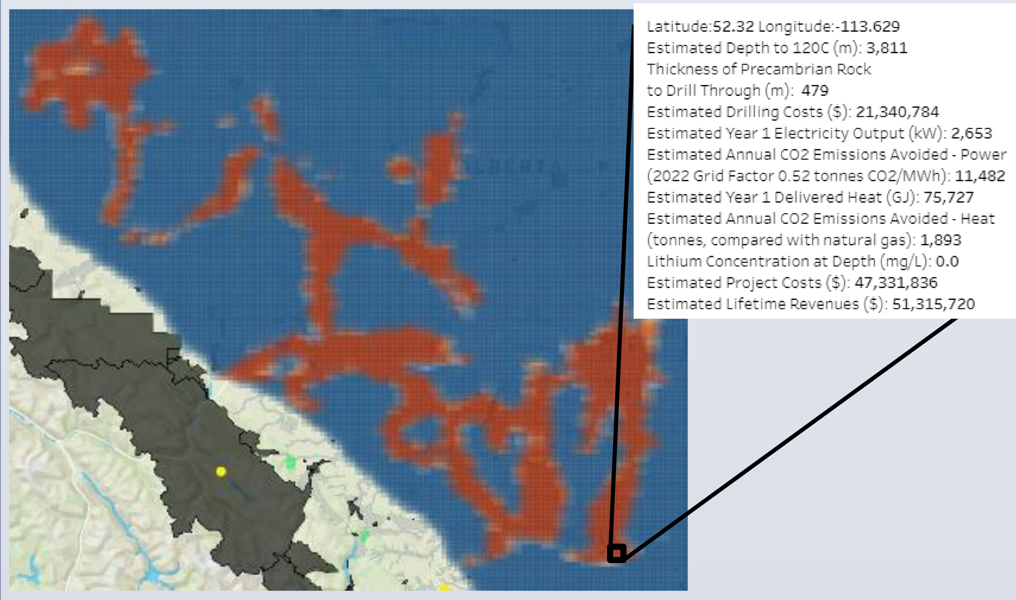
An interactive Net Present Value (NPV) map showing where projects were modelled to be economic (red cells) given user-defined variables such as Power Purchase Agreement price and flow rate is shown below.



Some of the first areas modelled to have a positive NPV for the 120°C scenario correspond to locations where geothermal developments are planned or operating (indicated with ☆).

Parks and Protected Areas: dark grey areas
Key Wildlife and Biodiversity Zones: light grey areas
Recorded Earthquakes (greater than magnitude 1): yellow points
Indigenous Communities/Indian Reserve Lands: green areas

The NPV map for approximately the same portion of Alberta given a 30% reduction in drilling costs, a net price of $50/kg of lithium (improving the economic viability of the Fox Creek region), and annual CO2 sequestration of 1,500 tonnes with net revenue of $100/tonne is shown below.



40°C Resource — Locations of First Positive NPV Projects:

- Grande Prairie
- Lacombe

80°C Resource — Locations of First Positive NPV Projects:

- Grande Prairie
- Fox Creek
- Lacombe
- Ponoka

120°C Resource — Locations of First Positive NPV Projects:

- Grande Prairie
- Fox Creek
- North of Chinchaga Provincial Park (approx. 100km S of Rainbow Lake)
- East of Edson
- Lacombe
- Ponoka
- West of Thorsby
- Rimbey

150°C Resource — Locations of First Positive NPV Projects:

- East of High Level
- North of Chinchanga Provincial Park (approx. 100km S of Rainbow Lake)
- Grande Prairie
- Fox Creek
- Whitecourt
- Swan Hills
- Leduc
- O'Chise Indian Reserve
- Northwest of Rimbey

CONCLUSIONS

- The regions in Alberta with the highest geothermal gradients do not necessarily correlate with the locations of the most economically viable projects
- A project's economic feasibility is heavily dependent on a theoretical reservoir's ability to generate flow rates generally exceeding 45kg/s per production well. Project economics are also very sensitive to costs to drill, costs to link into surface infrastructure (roads or transmission lines), and a project's ability to sell heat to nearby customers
- An interactive model was published online that shows changes to the NPV map under variable conditions (e.g. drilling cost reductions, resource flow rates, or if a project proponent is only required to pay a portion of the costs to build infrastructure to a development)
- Try the interactive models for 40°C & 80°C (direct-use heat), 120°C & 150°C (heat +power) at https://public.tableau.com/app/profile/gordon.brasnett or:

FUTURE WORK:

- This work was completed using a 5 x 5 km grid. A higher resolution model could be developed (section or quarter-section scale)
- Cost layers associated with land classifications and waterway crossings could be applied to create better regional estimates for road and transmission line construction
- Geologic porosity/permeability information could be integrated for improved flow rate and reservoir stimulation cost estimates
- Drilling cost models that use run length, trip time, rate of penetration, and add more detailed information about drilling through assorted rock type (carbonates, sandstones, basement, etc.) could be included

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ACKNOWLEDGEMENTS AND CONTACT

Acknowledgements: Gordon Brasnett is a student at the University of Calgary and acknowledges the support of the Mitacs Business Strategy Internship program funded via the Government of Canada and Alberta No. 1 (ABNo1).

ABNo1 is partially funded through Natural Resource Canada (NRCan) Emerging Renewal Power Program (ERPP), and the authors acknowledge the support provided through this program.

Geothermal gradient data was generously shared by Jacek Majorowicz PhD, University of Alberta (retired). These geothermal gradient maps represent years' worth of data collection and analysis, the authors thank Dr. Majorowicz for sharing this information as this project would not have been possible without it.

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