Geothermal Play-Fairway Analysis of Washington State Prospects

Project Officer: Laura Merrick

Total Project Funding: $1,095,605.00

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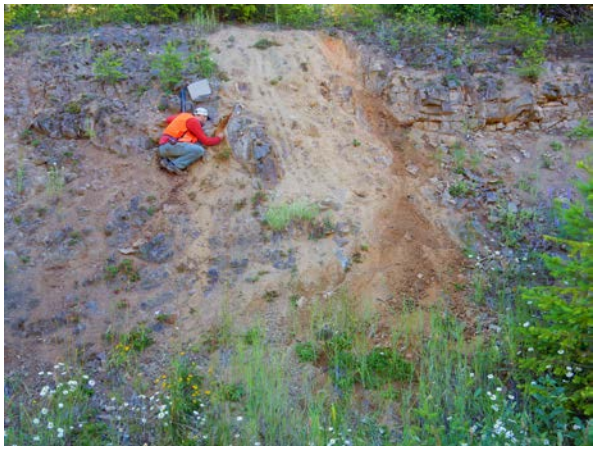
Washington Geological Survey
WA Department of Natural Resources

Play-Fairway

Relevance to Industry Needs and GTO Objectives

- Understanding geothermal resource potential in an underexplored region of the U.S. As WA pushes to achieve 15% of energy from renewables by 2020, geothermal could play a vital role. Studying and testing the play-fairway approach enhances knowledge of the area and the conceptual model.
- Upfront funding from DOE and cost share from Washington Geological Survey (WGS) will greatly reduce cost for future interested parties. Washington is behind other western states in terms of geothermal exploration. Addition of new data and upcoming TG wells will help to advance the state of knowledge.

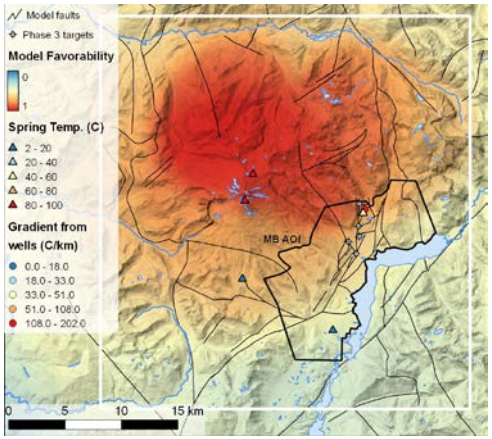


Relevance to Industry Needs and GTO Objectives

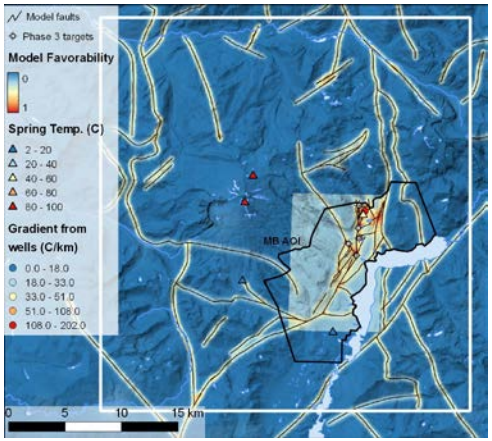
- Developing a PFA method that can be used to identify resource potential, certainty, and exploration risk for all geothermal systems

Uses existing data and newly collected data to analyze the likelihood of a confluence of geothermal indicators related to:

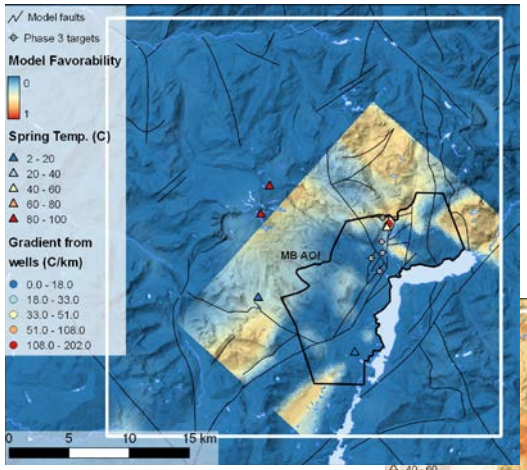
- Heat
- Permeability
- Fluid Filled Fractures
- Infrastructure



Heat

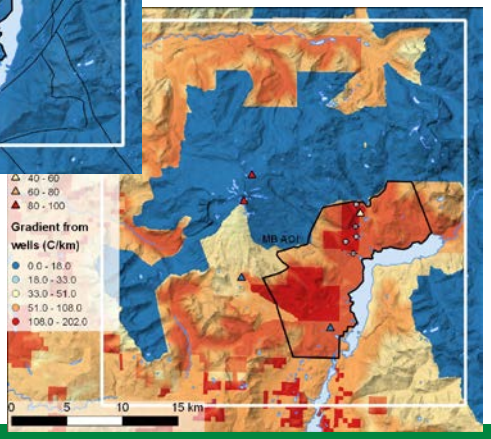


Permeability

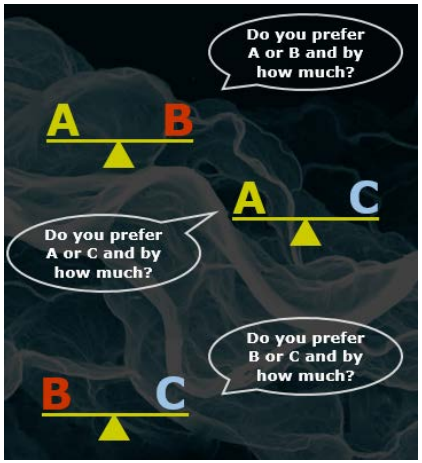


Fluid Filled Fracture

Infrastructure



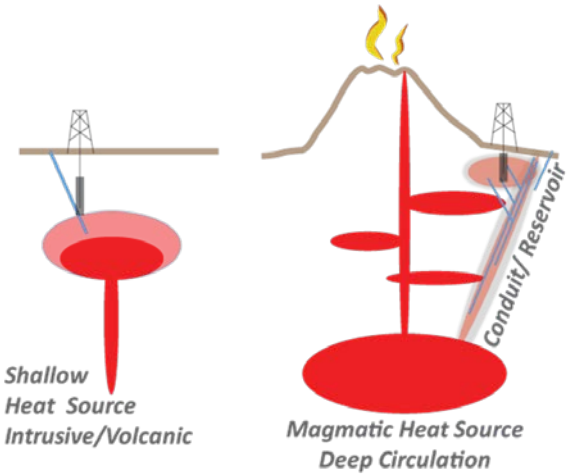
- Use the Analytical Hierarchy process to weight input parameters from expert opinion.



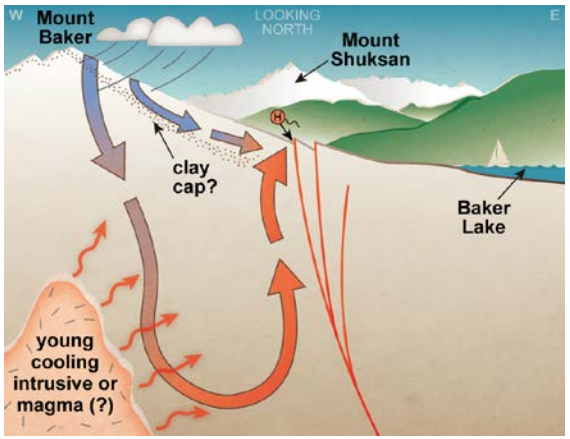
Relevance to Industry Needs and GTO Objectives

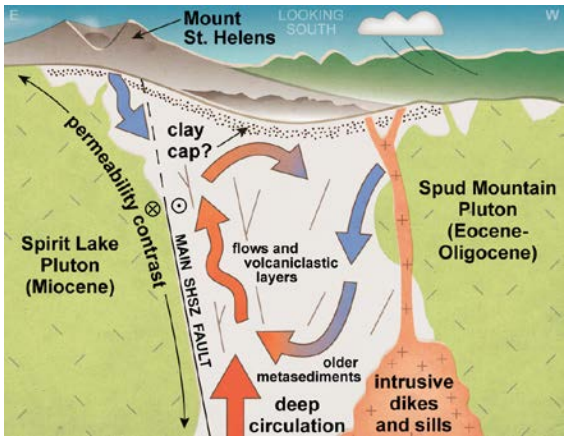
Starting from a conceptual model and building on to it as we learn more and collect more data.

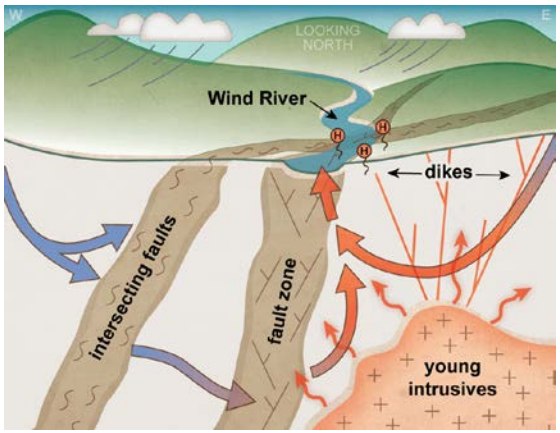
Phase 1 conceptual models



Phase 2 conceptual models

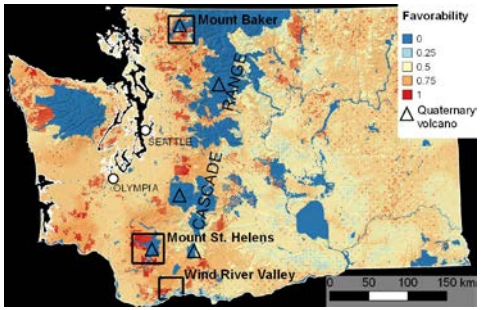






Relevance to Industry Needs and GTO Objectives

- Successes impacting the GTO's goals:
  - Developing a PFA method that can be used to identify resource potential, certainty, and exploration risk for all geothermal systems
  - Infrastructure model identifies where there could be issues with:
    - environmental permitting
    - Land use
    - proximity to transmission lines and major roads
    - Distance to urban centers sensitive to induced seismicity
    - And elevation restrictions



  - Supporting collaboration and early-stage research to acquire new data and develop a methodology that identifies potential blind geothermal resources
  - Exploration in an underexplored region of the U.S.
- This is a 3 phase project:
  - **Phase 1** was a desktop study using existing data to find geothermal resource potential, uncertainty, and risk
  - **Phase 2** focused in on higher potential regions. New data was collected tp address uncertainty and each play was re-analyzed for favorability, certainty and exploration risk using the new data
  - **Phase 3** focuses on validating the method and improving certainty by drilling, comparison of methods, and a detailed structural analysis

Methods/Approach

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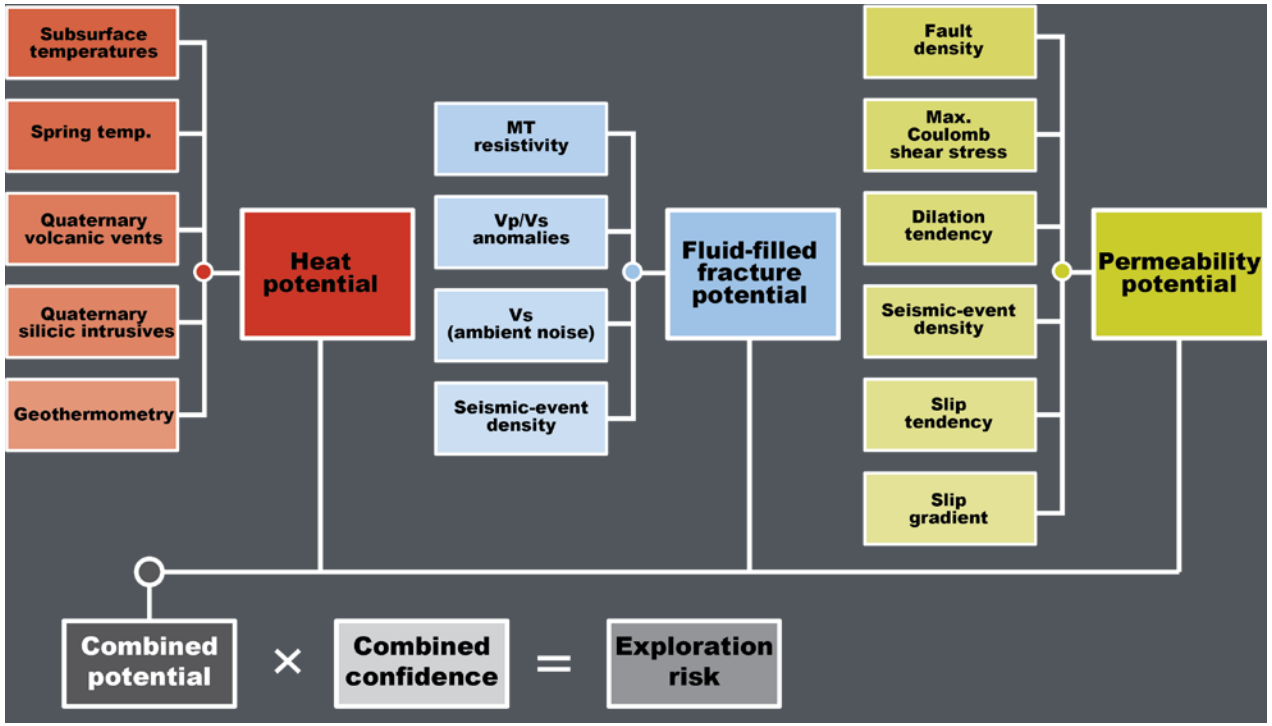
Combined existing and newly collected data to come up with favorability, certainty, and risk models to help identify geothermal targets and lower exploration risk by assessing certainty.



Phase 2 data added:

- Ground-based gravity
- Ground-based magnetics
- Lidar interpretation+
- Aeromagnetics*+
- Modeled cross sections+
- MT
- Passive-seismic
- Geologic mapping
- $^{39}Ar/^{40}Ar$ geochronology
- Electrical-resistivity

*existing data added
+new data at no cost

Methods/Approach

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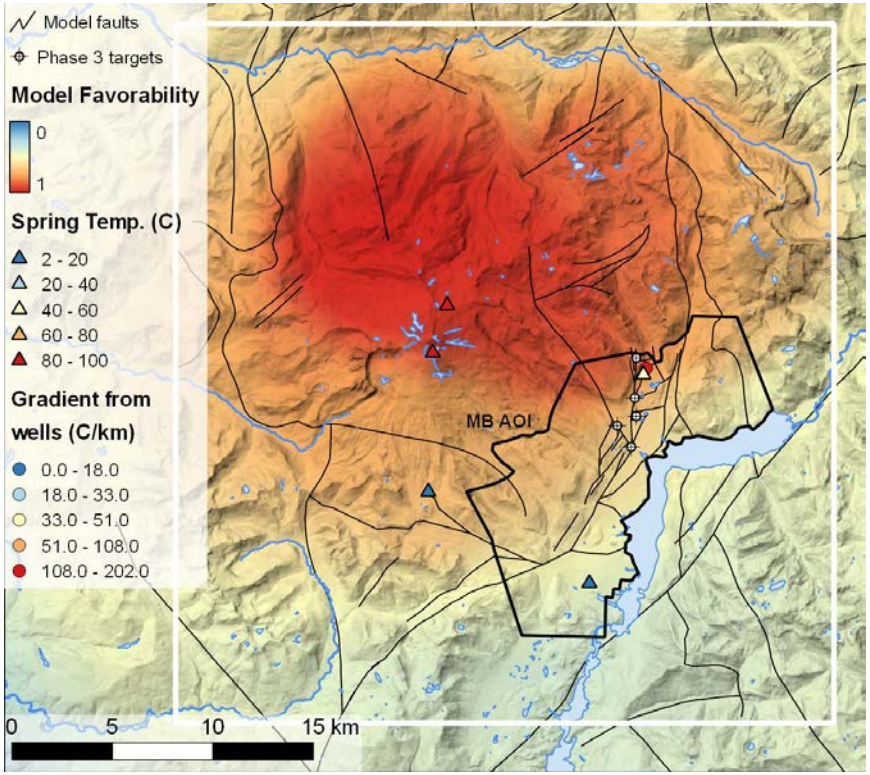
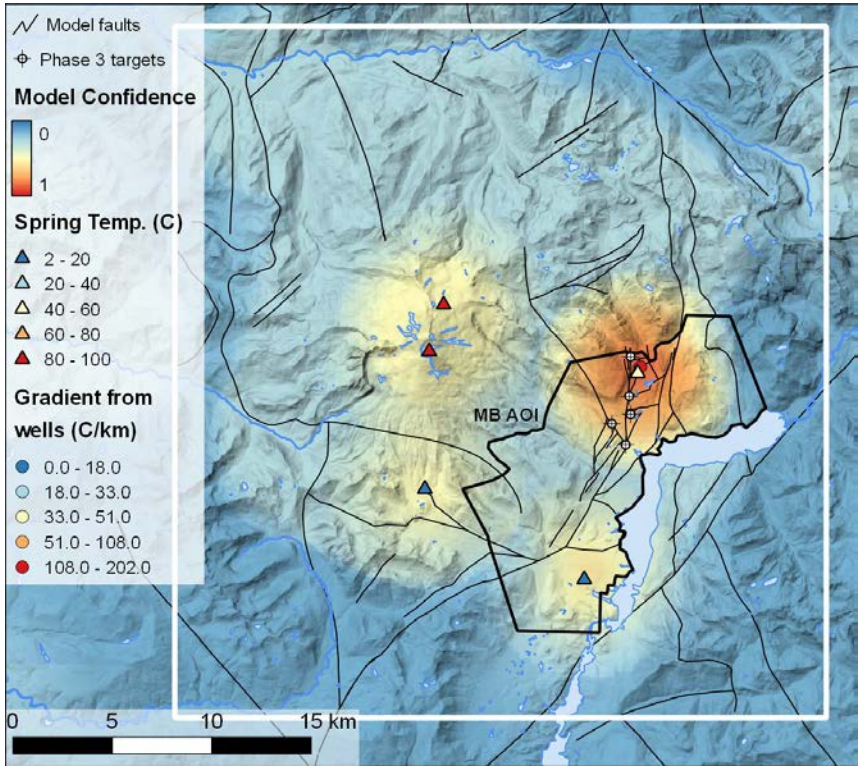
Heat potential is assessed through a combination of subsurface temperature observations, the distribution and age of igneous rocks, spring temperature, and geothermometry.



Potential



Confidence

Methods/Approach

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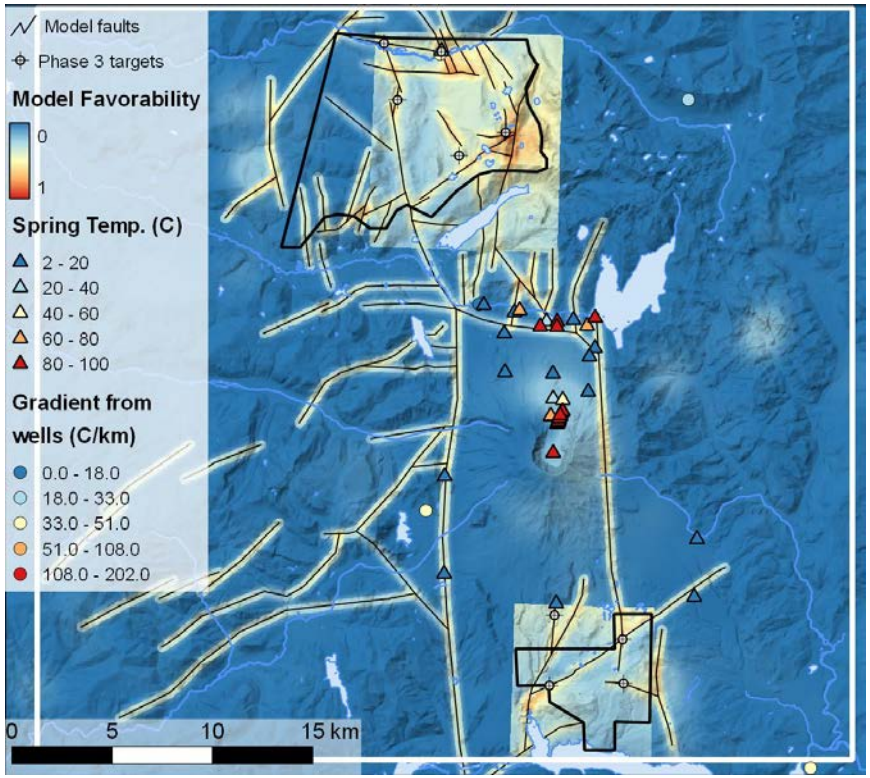
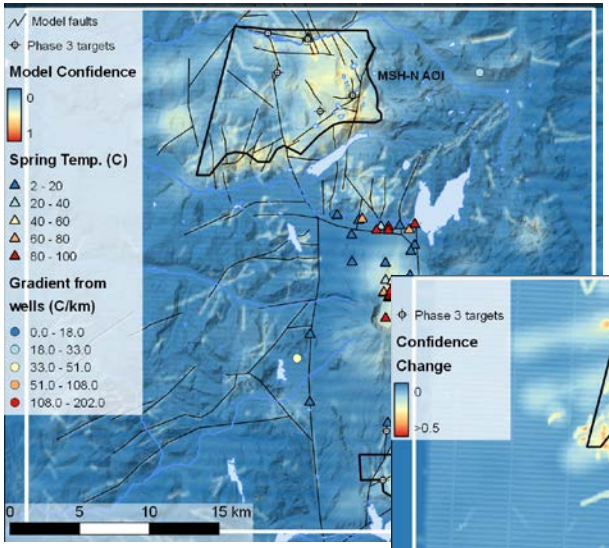
Permeability potential is assessed by developing 2D and 3D geomechanical models along previously or newly identified faults and the sub-regional stress/strain field. These models predict regions of dilatancy, slip tendency, and maximum shear stress and are combined with maps of seismicity and the density of mapped faults.

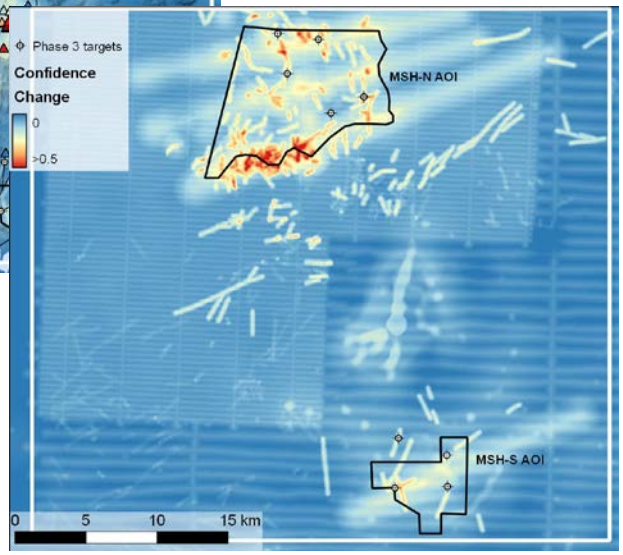


Potential



Confidence

P1-P2 Change



Methods/Approach

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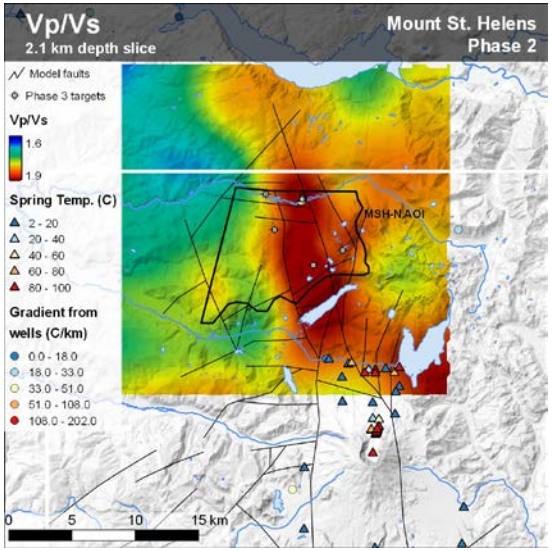
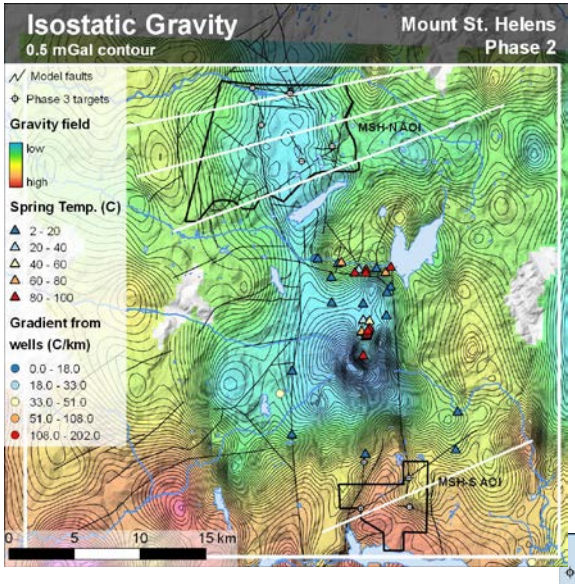
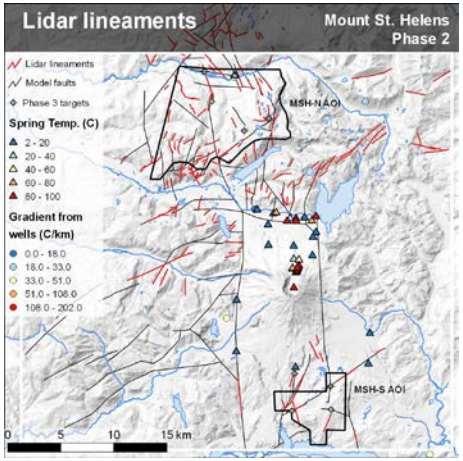
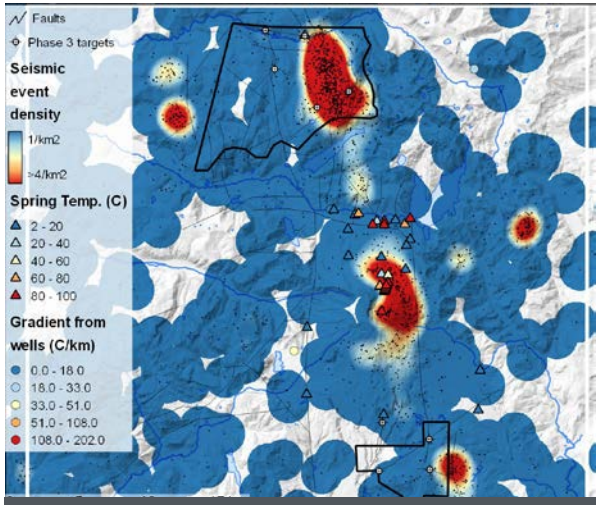
Much of the new data collected was to improve permeability potential model



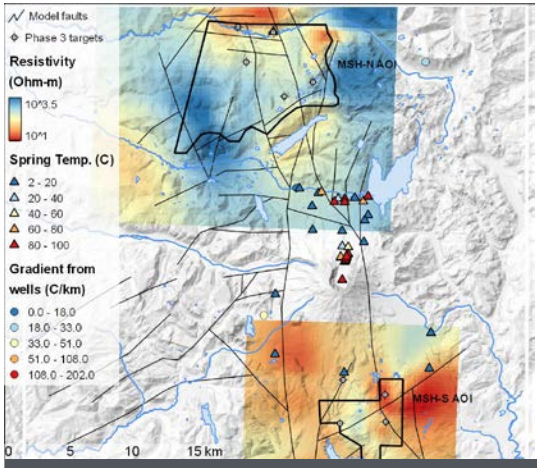




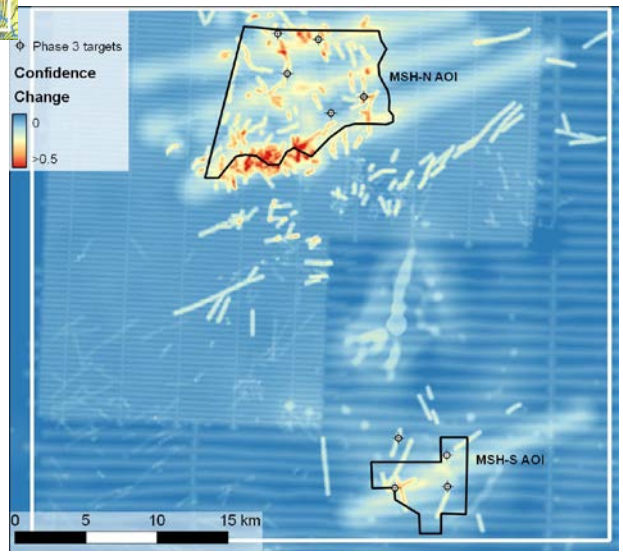
P1-P2 Change



Seismic Event Density



MT Resistivity



Methods/Approach

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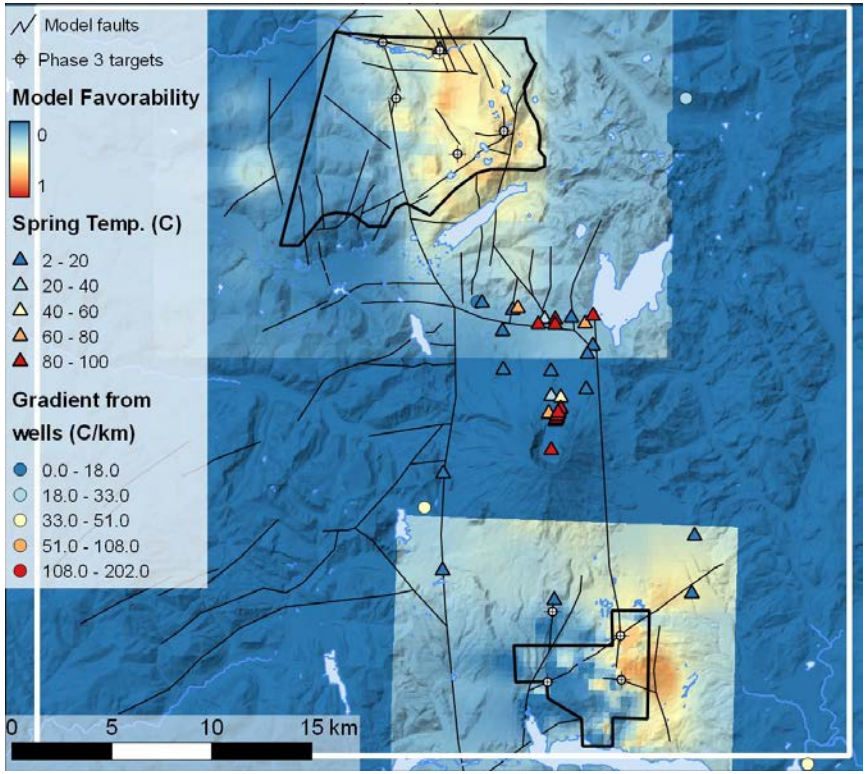
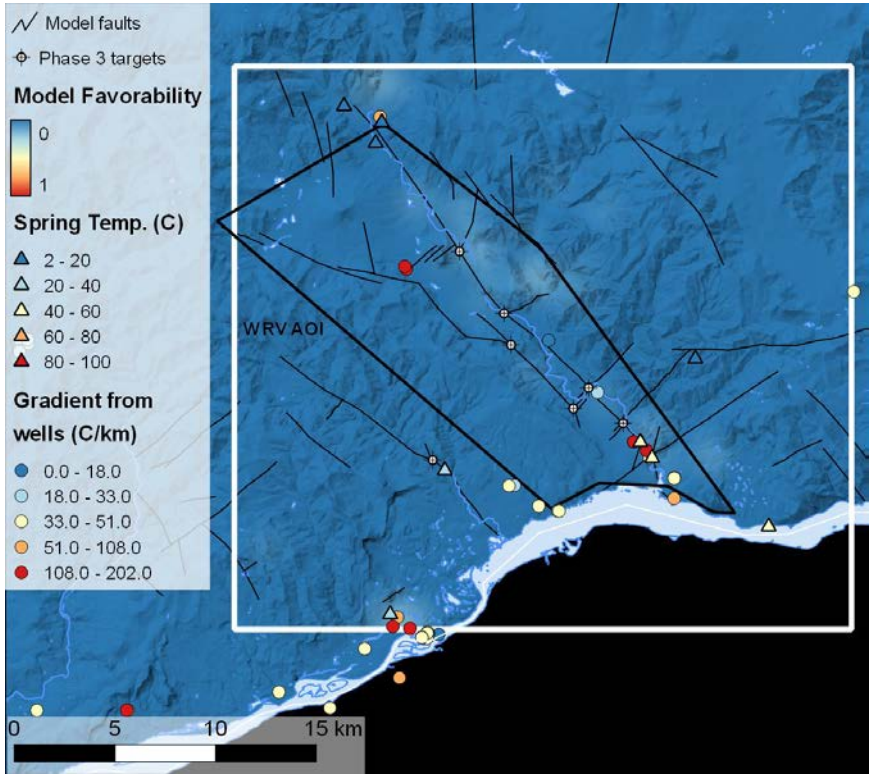
Reservoir potential is assessed with 3D models of resistivity, seismic-event density, and passive-seismic results (ambient noise Vs and Vp/Vs ratios).

Highly dependent on data availability



Potential MSH



Potential WRV

Methods/Approach

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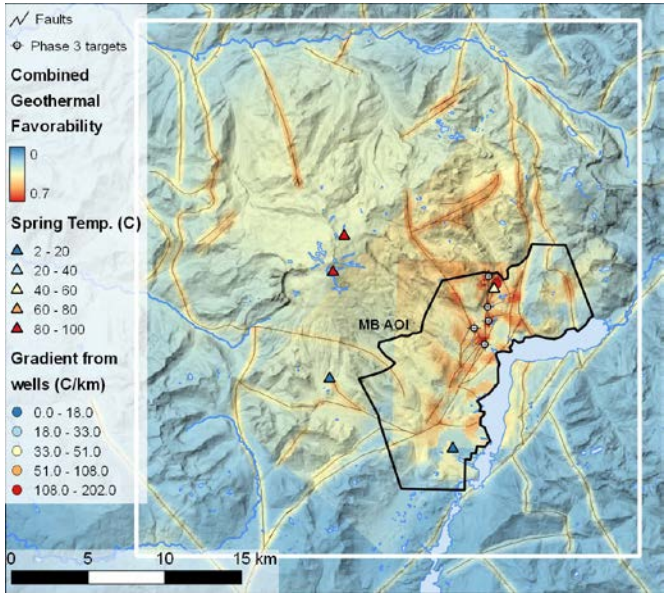
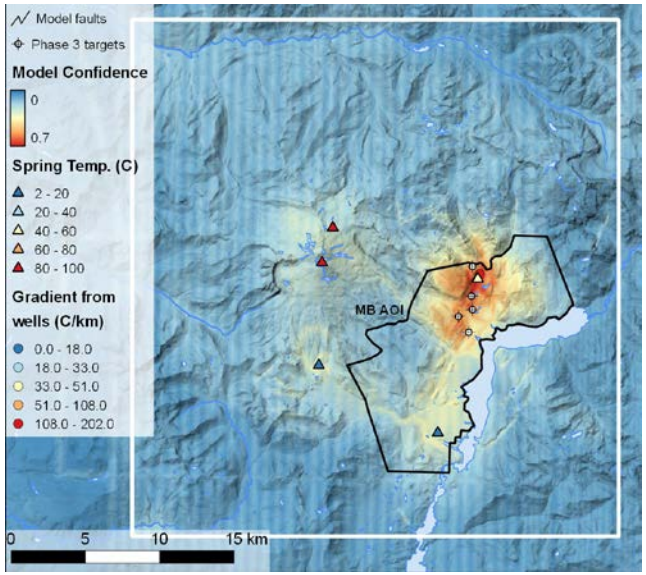
Combined Models



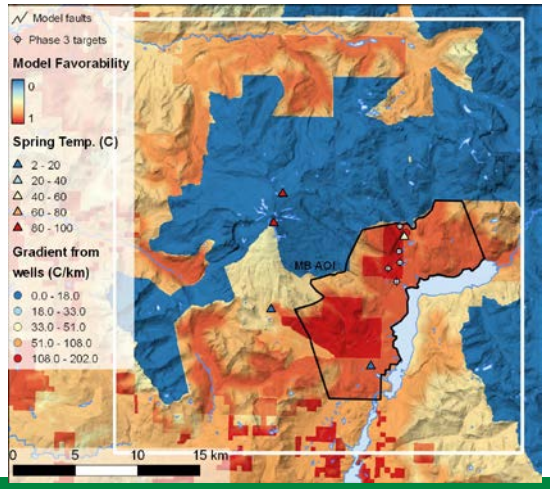
Potential

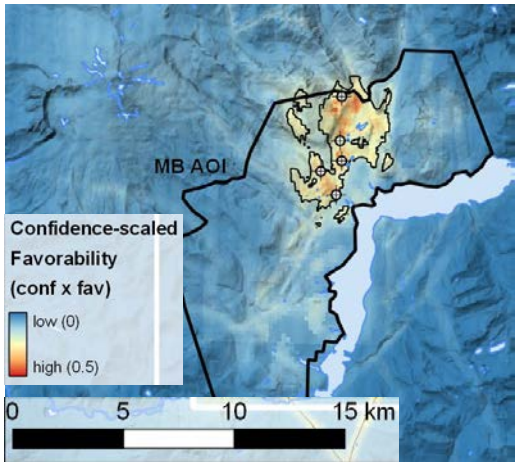
H = 32 %
P = 34 %
F = 33 %

Confidence



Infrastructure





Confidence scaled favorability

Technical Accomplishments and Progress

- **Accomplishments/Progress to date:**
  - Our PFA method integrates the best available science and state of knowledge of what it takes to make a geothermal resource
  - Successful completion of collecting, processing and incorporating vast amounts of data into revised models
  - All projects were completed on time, and on-budget
  - Phase 2 was a very involved field campaign with 7 teams, each with 2-4 people collecting data at 3 field sites all summer long. Everyone collaborated, adhered to field safety protocol, and did a stellar job!
  - The biggest challenge was working with so much data and so many people on such a short timeframe. We only had 1 field season to collect all data, and had to process and interpret the results in about 6 months.
  - We applied for a no-cost extension to allow us to present at the Geothermal Resources Council Meeting and to have a bit more time to write a final report and submit data to GDR.

Technical Accomplishments and Progress

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SOPO Task	Title	Planned Milestone/ technical Accomplishment	Actual Milestone/Technical Accomplishment	Date
5	Contracting, permitting, and planning	Negotiate award, subcontractor contracts, NEPA submission, logistics planning	Final Budget Period 2 contract signed, sub-contracts signed, USGS contracts signed, work plans determined for field surveys, NEPA issues determination of non-significance that permits field work to commence	Feb. 2016
6	Data Collection	Field-based data collection from all three play areas	Field activities will begin as soon as NEPA is approved for that specific activity and as weather and ground conditions permit	May 2016
6.1	Geologic Mapping	Mapping, field surveys, and sample collection from all three play areas	Geologic data collected from mapping and field surveys by WGS	Aug. 2016
6.2	Resistivity Surveys	Resistivity surveys at MSH and MB	Resistivity data collected	Aug. 2016
6.3	Passive Seismic Survey	Deployment, monitoring, and data collection from passive seismic array at MSH	Successful download of seismic data from deployed array with USGS partners	Aug. 2016
7	Data Processing and Interpretation	Data processing, analysis, and interpretation	Contractors deliver processed data and partners collaborate on data interpretation	Oct. 2016
8	Favorability Modeling	Incorporate new data into favorability models for all three plays	New favorability models generated for all three plays	Dec. 2016
9	Uncertainty and Risk Modeling	Incorporate new data into uncertainty and risk models for all three plays	New uncertainty and risk models generated for all three plays	Feb. 2017
10	Reporting	Final technical reporting and presentation	Final technical reporting completed, presentation to DOE, TMT review, discussion of Budget Period 3 decision point	Jun. 2017
11	Data Submission	Data submission of deliverables to NGDS	Data uploaded to NGDS with complete metadata	Dec. 2017

Special recognitions: Corina Forson won Best Speaker at GRC 2016 for PFA talk
This is good for promoting the project and getting people interested in geothermal potential in WA

Research Collaboration and Technology Transfer

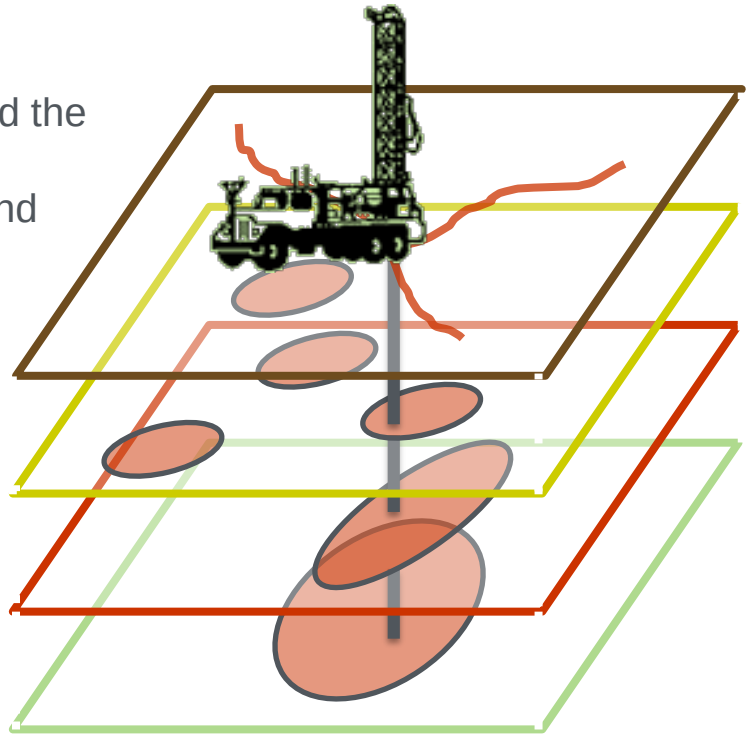
- The Washington Geological Survey has been working with the Lease Division at the Washington Department of Natural Resources to evaluate geothermal opportunities on State-owned land.
- The Survey has also been working closely with a legislative advocacy group that seeks to encourage renewable energy development.
- AltaRock Energy, Inc. has used the methodology developed during this project to explore for geothermal potential in other areas of the Pacific Northwest.
- Several groups have recently approached our organization about opportunities for large-capital moderate- to high-temperature geothermal development and are very interested in the results of Phase 3 drilling results.

Future Directions

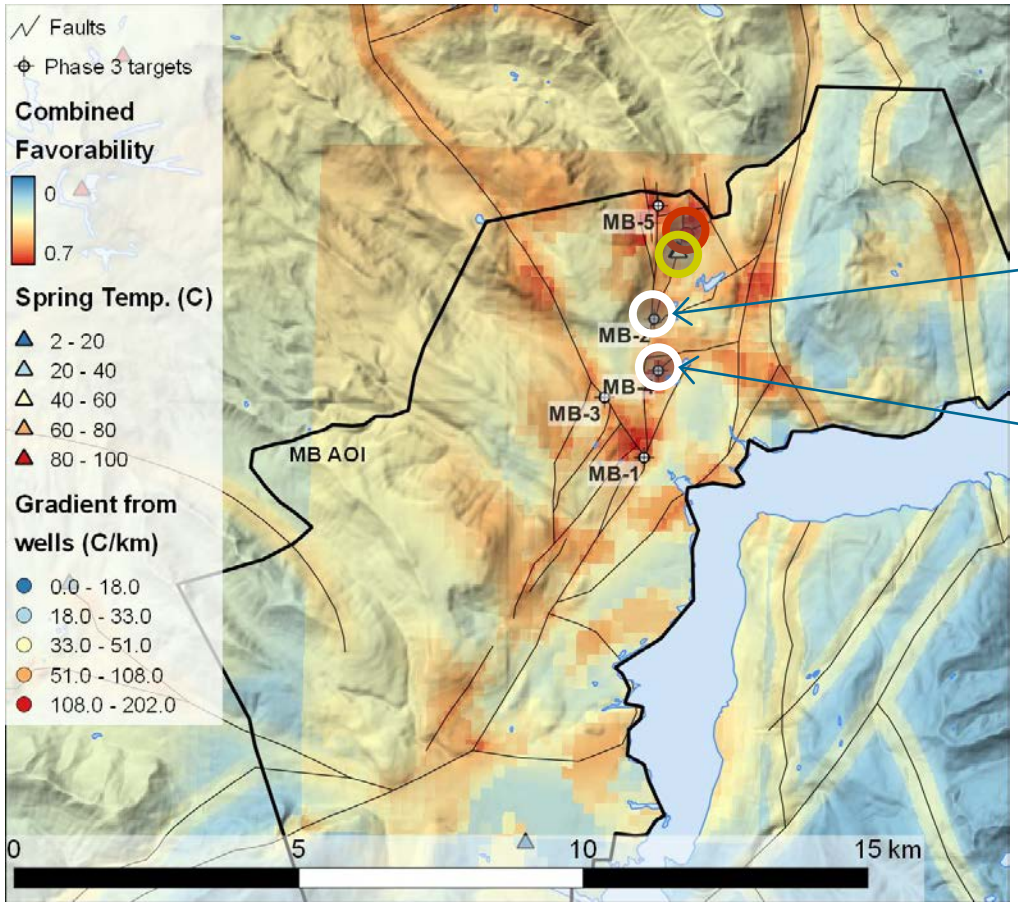
Phase 3 Awarded

The primary objective of Budget Period 3 is to validate the models and methods developed during Periods 1 and 2 and provide these results to potential developers. There are three main validation activities:

- (1) drill up to 5 new temperature-gradient holes at sites identified by the Phase 2 models as being the most favorable for geothermal potential;
- (2) undertake a method comparison by using the method developed by the USGS for the Snake River Plain PFA and the Washington PFA data;
- (3) perform detailed structural analysis of core, cuttings, and image logs from the new temperature-gradient holes.



Additional Information



Site	Combined potential	Combined confidence	Depth (ft)
MB-1	0.61	0.47	1,600
MB-2	0.50	0.65	1,600
MB-3	0.46	0.6	1,600
MB-4	0.64	0.54	1,600
MB-5	0.64	0.54	1,600
Mount Baker Hot Springs (44 °C)	0.48	0.68	– – –
DNR83-3 TGH (200 °C/km ?)	0.62	0.63	460

Phase 3 drill site selection

Future Directions

Task or Subtask (if applicable) Title	Milestone Description (Go/No-Go Decision Criteria)	Milestone Verification Process (What, How, Who, Where)
Land access, Site Visits	Visit, evaluate, and document the suitability for drilling at each potential drill site.	WGS will work with USGS to determine needs and visit each site to document/assess
Prepare and Submit Permits	Prepare and submit paperwork for NEPA, SEPA, drilling permit	WGS will work with agencies to develop and submit required information
Provide Data to USGS for PFA comparison	Package and deliver the WA PFA data for USGS use	WGS will deliver data in format as required to USGS
Drill Site Plan	Provide drilling plan to USGS	WGS will verify site conditions, determine order of drill sites, and provide information to USGS
Planning and drilling of as many as 5 TG wells.	Identify and address site issues and permitting requirements	WGS will work with USGS drillers and DOE management under scope of permits
Site cleanup and lessons learned	Oversee site cleanup, sample management, and drilling documentation	WGS will oversee site cleanup and de-mob. WGS, with input from ARE and TU will document lessons learned from drilling to be applied to future drilling
Core Analysis	Detailed analysis of core and image log	TU will perform analysis of the recovered core and image logs
Structural analysis	Detailed analysis of fracture type, orientation, and history	TU will perform analysis.
Log Temperatures	Log temperature vs depth at each completed hole.	WGS will measure data, compute heat flow from conductivity measurements, and share with project partners.
Plug and Abandon Holes	Each hole will be plugged and abandoned as per permits	WGS will oversee work performed by USGS.
Process Data/Model Refinement	New data will be processed and integrated with PFA models	WGS, with advice from ARE and TU will perform this work.
Reporting	Final technical reporting and presentation	Final technical reporting completed, presentation to DOE and TMT review
Data Submission	Data submission of deliverables to NGDS	Data uploaded to NGDS with complete metadata

Summary Slide

- Phase 1 was successful at identifying targets for further exploration
- Phase 2 collected heaps of new geological and geophysical data and helped to expand knowledge of the “sweet spots” at each play
- Phase 3 will focus on validating the method and drilling 4-5 TG wells to 1,600 ft to test the model and see if there is enhanced heat and permeability
- Investment by GTO has advanced the state of knowledge of the geothermal potential of an underexplored region of the U.S. and attracted some industry interest. Now let’s hope for a successful drilling campaign.