New Exploration Methods Applied to Previously Studied "Known Geothermal Resource Areas" in Southern Idaho and Eastern Oregon

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Project Focus

This project seeks to reconsider geothermal sites in a large area of the western USA (Figure 1). For more than 30 years, parts of eastern Oregon and southern Idaho, and northern Nevada and Utah have been characterized as Known Geothermal Resource Areas (KGRA) (Burkhardt et al 1980)). Many of these areas have not been rigorously explored or were evaluated using traditional exploration techniques, some of which may be out of date. In most cases in our study area, the limited exploration has not revealed the existence of commercial temperature resources worthy full-scale exploration. Technologies for generating electrical power from water with lower temperatures have advanced significantly since the late 1970's. New geothermal technologies may make some of the KGRA's viable. We hypothesis that within these KGRA's, there are some number of under characterized prospective geothermal prospect with elevated heat flow that could be commercial grade resources. The objective of this project is to provide a fresh look at these systems using modern exploration tools and techniques to identify and elevate hidden KGRA prospects to a status that warrants further exploration. We propose a new paradigm for evaluating these systems that is based on the application of 21st century tools and techniques, including the integration of geochemistry, structure, modeling and data analysis, and data visualization (3-D CAVE technology) techniques. Our work will lead to a methodology that will enable more effective evaluation of other underdeveloped geothermal resources.

FY15 objectives

•Revisit KGRA's identified in the past (e.g. Burkhardt et al., 1980) and develop a framework for screening sites to focus application of "New Exploration Methods."

•Focusing on two case studies, aggregate new data collected over the past 5 decades to include literature studies, interviews of scientists who conducted past studies, and gather information and data that is not in the literature.

•On a select subset of sites, use modern geochemical tool, such as multi component thermometers, (Palmer 2014: Neupane et al, 2015) isotopic geothermometers, and noble gas analysis to prove that concept that some portion of these previous explored or neglected geothermal systems may be worthy of a higher prospect status using the proposed integrated exploration methods?

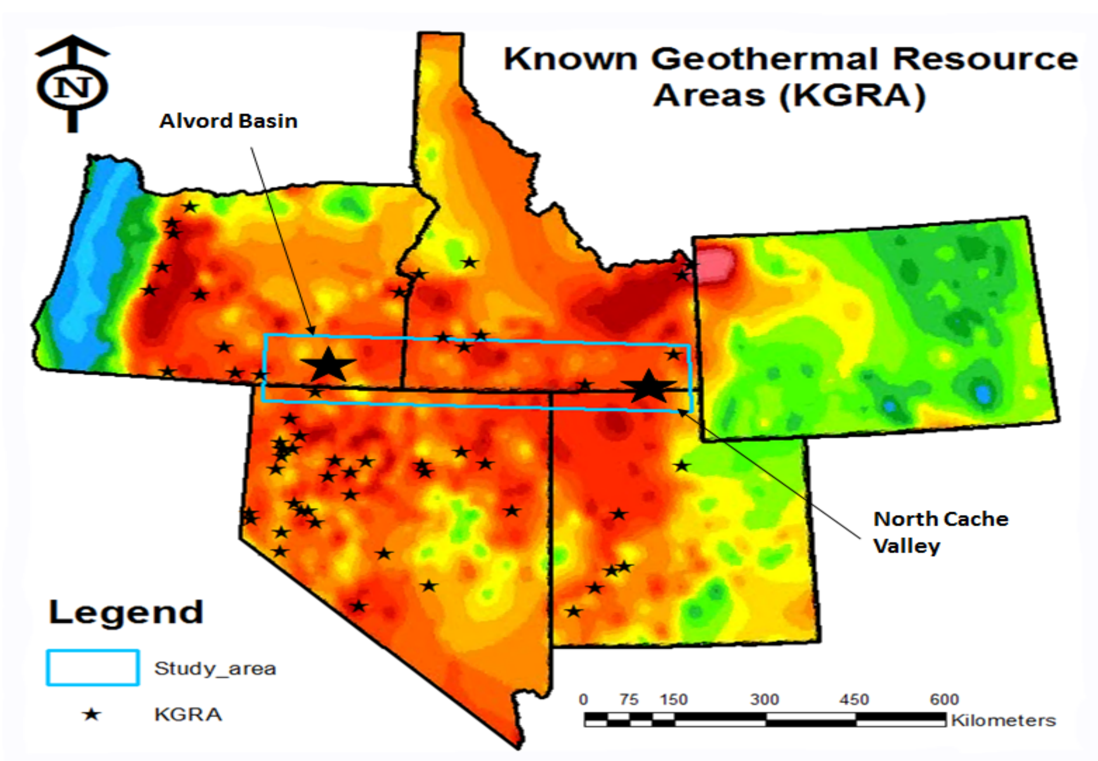

Figure 1. Known Geothermal Resources (KGRA) in Idaho, Utah, Nevada and Oregon. Modified from Blackwell et al, 2011. This study is being conducted across a 75,000 km^2 area that has a long history of geothermal interest, but very few producing power plants. The team hopes that through the application of new techniques and tools to the regions KGRA's some will be advanced to prospect status. The two test cases discussed in this poster are the North Cache Valley and Alvord Basin.

Focusing Our Effort

This project will produce a methodology for identifying promising geothermal prospects from KGRAs that have not been seriously investigated for decades or have been overlooked entirely. One product will be a set of ranking criteria to focus efforts on the best KGRAs for re-evaluation. As a first step, we are reviewing in detail the histories and studies of two KRGSs. Understanding the geologic, geophysical, geochemical, and other techniques employed in the past is key for defining ranking criteria that are meaningful. Our case studies include the North Cache Valley area of southeastern Idaho and the Alvord Basin in eastern Oregon. Both of these KGRA's have rich histories of geothermal interest that will be useful for populating our ranking criteria. The North Cache Valley hosts the Preston Prospect, which was recently rediscovered when a water well encountered boiling water at a depth of 79 meters. Early exploration efforts in the Alvord Basin resulted in a 451 m deep well with flowing temperatures of 152˚C (Cummings et al., 1993), but environmental restrictions have resulted in no additional commercial exploration in this area, which makes it an ideal case for beta testing our methodology.

In addition to the identification and evaluation of existing data, the team will identify and collect geothermal water samples to address critical data gaps. The aforementioned ranking criteria is in the draft stage and will be tested with data collected during the upcoming field season. Once the ranking criteria is fully tested, it will be applied to the KGRA's in Figure 1 and the down selected KGRA's will be evaluated during FY16.

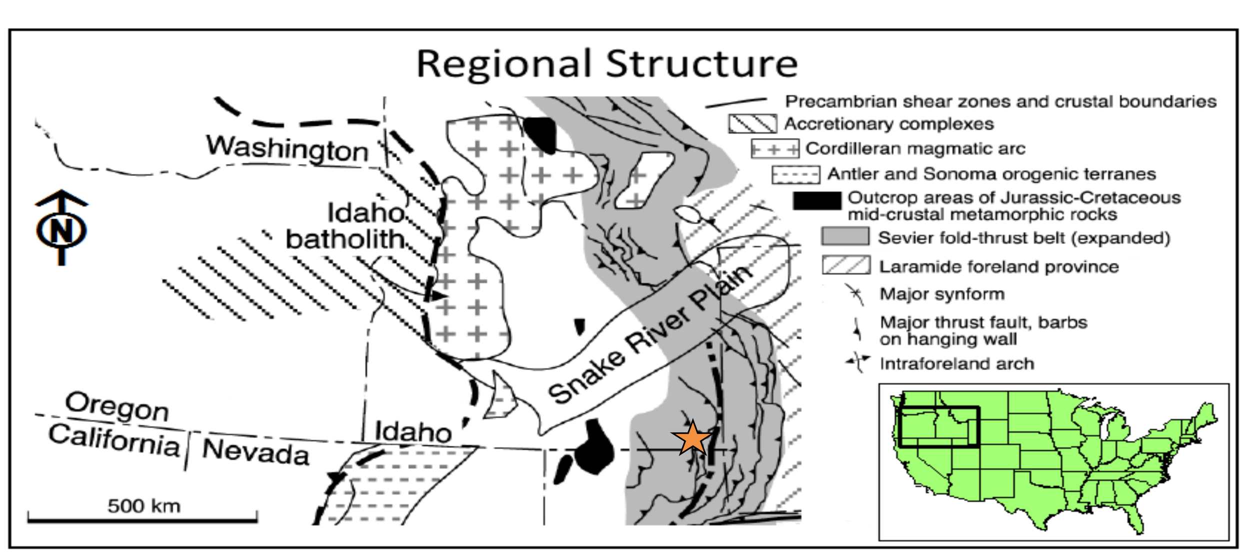

Figure 2. Regional structures at the confluences of Idaho, Wyoming, Utah, Nevada, California, Oregon, and Washington. The orange star indicates the position of the North Cache Valley. Modified from DeCelles, 2004.

Regional Setting of the North Cache Valley

The North Cache Valley (NCV) is a northward trending valley located in southeastern Idaho and northern Utah. It is situated at the confluence of several geologic terrains on the northeastern extent of the Basin and Range Province where it meets the Sevier orogenic belt and Rocky Mountains (Figure 2). The juncture of these provinces is characterized by seismic activity and clusters of hot springs (Sbar et al., 1972). It is underlain by the western portion of the Idaho Thrust belt, which formed in the Sevier orogeny, active from late Jurassic to the late Eocene, 140-70 million years ago (m.a.) (Grubbs & Van Der Voo, 1976). The Rocky Mountains were formed during the Laramide orogeny, lasting from the late Cretaceous (70-80 m.a.) to the early/late Eocene (35-55 m.a.). Basin and Range extension began in the early Eocene, approximately 45 m.a., and continues to the present. The province is characterized by repeating sequences of paired normal faults (i.e. graben forming), accommodating the extensional forces and stretching the area to double that of its original width. Because the NCV is located at the convergence of structurally distinct and active provinces, it is influenced by many forces and processes that may influence the occurrence of sources of geothermal heat and secondary sources of permeability. During the first 12 months of this project, existing structural, geological, geochemical, geophysical, and hydrologic data from previous studies conducted in the region of interest will be evaluated and integrated into a GIS database with special attention being given to extract "lessons learned" from previous exploration efforts.

Understudied KGRA Test Cases

Preston Geothermal Prospect, Idaho

The Preston Geothermal prospect is located in Northern Cache Valley (NCV), a northward trending valley located in southeastern Idaho (Figure 1). This is a known geothermal resource area (KGRA) that was evaluated in the 1970's by the State of Idaho Department of Water Resources (IDWR) and by Sunedco Energy Development. In January of 2014, interest was renewed in the area when a water well drilled to 79 m (260 ft) yielded a bottom hole temperature of 104°C (217°F) (Wood et al., 2015). Traditional magnesium corrected Na-K-Ca geothermometry estimates this new well to be tapping water from a thermal reservoir of 227°C (440°F): the water chemistry and Na-K Giggenbach temperatures for other thermal features in this area are depicted in Fig. 6. This new data set provides strong support for further investigation and sampling of wells and springs (Figure 3) in the Northern Cache Valley, proposed for the summer of 2015. The shallow thermal anomalies appear to be constrained by fault-controlled fluid flow (Figures 5 & 7).

Alvord Basin Oregon (test case only)

A similarly exciting prospect exists in the Alvord Basin in southeastern Oregon, where three groups of high (70-95°C) temperature thermal features (Mickey HS., Alvord HS, and Borax Lake) are found (Figure 4). The Alvord Basin is a north-northeast-trending graben in the northeastern Basin and Range Province. Studies of fault zone hydrology have shown strong lateral variations in permeability with localized fast paths for fluid flow (Fairley & Hinds, 2004). An exploration well drilled in 1989 to a depth of 451 m flowed at a rate of 400 gpm with a flowing temperature of 152° C (Cummings et al., 1993). High-temperature spring water compositions have indicated subsurface equilibration temperatures of 200-250°C (Nicholson et al., 2004).

Figure 3. Dilapidated structures remaining from the Squaw Hot Springs, Northern Cache Valley, Idaho. This spring is near the southern extent of the Preston Geothermal Prospect. The springs discharge 73 °C water and a well drilled on the property yielded 84 ° C water (Mitchell, 1976). RTEst results predict a reservoir temperature of 179 ° C (Wood et al., 2015).

Figure 4. Mickey Hot Springs, Alvord Basin, Oregon. This is one of three thermal areas in the Alvord Basin, and has a discharge temperature of 94˚C (Cummings et al., 1993). Detailed work on the hydrology of the fault-controlled Alvord Hot Springs has been conducted by Fairley and Hinds (2004) and Fairley and Nicholson (2006). Cation geothemometry suggests reservoir temperatures of 200-250 ˚C (Nicholson et al., 2004).

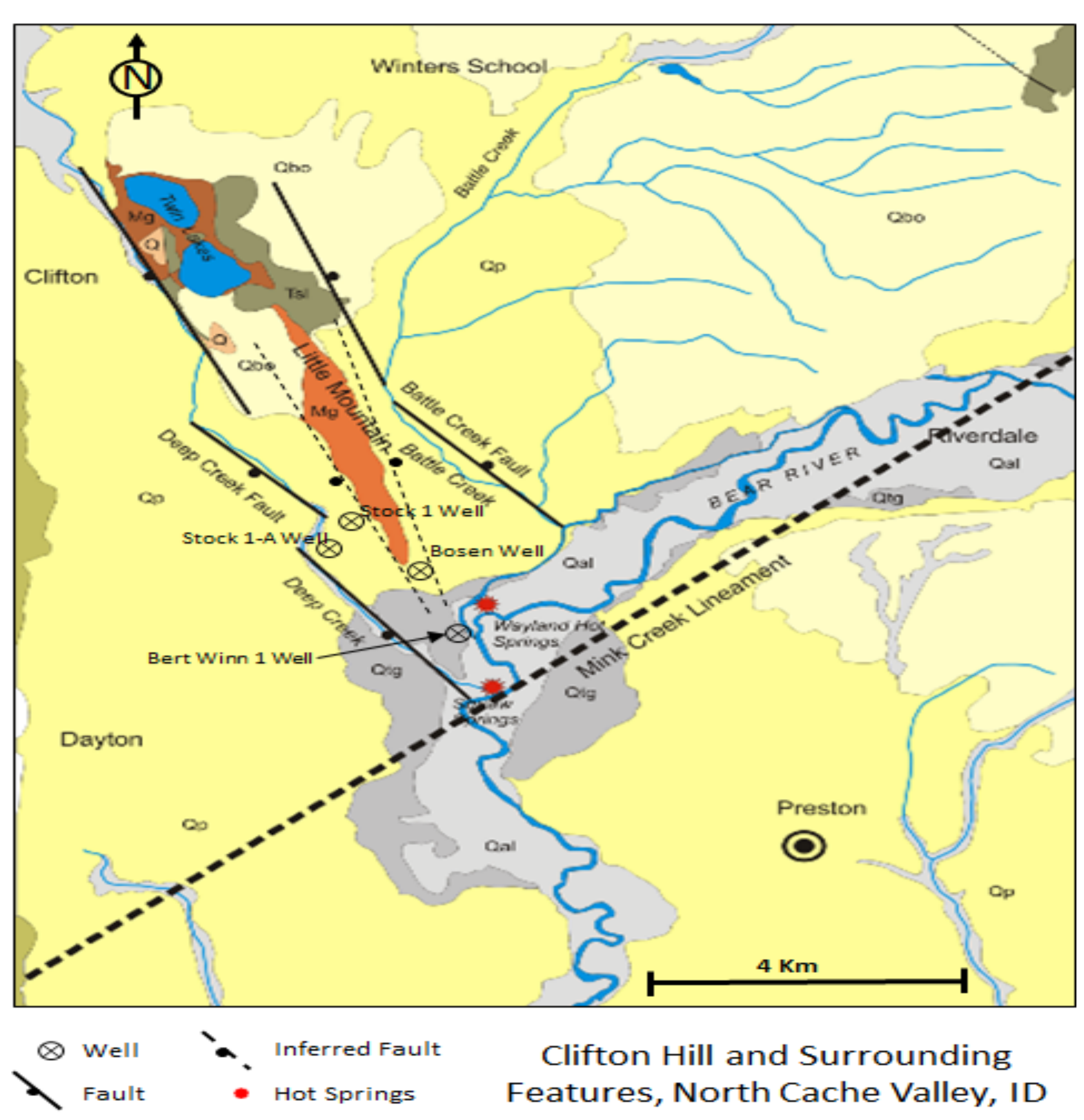

Figure 5. Map of Clifton Hill area and structural features of the NCV. Modified from an image courtesy of Dr. Ismail Kuscu of Blackrock Geosciences. Clifton Hill is also called Little Mountain as it is labeled here. Structurally it is a horst block as depicted in the cross section in upper right of poster. The Stock 1 well is 455 m deep; Stock 1-A is 1670 m deep with a temperature of 93° C at 91 m and the Bert Winn 1 Well is 2433 m deep with a temperature of 66° C at 91 m (McIntyre and Koenig, 1978; 1980).

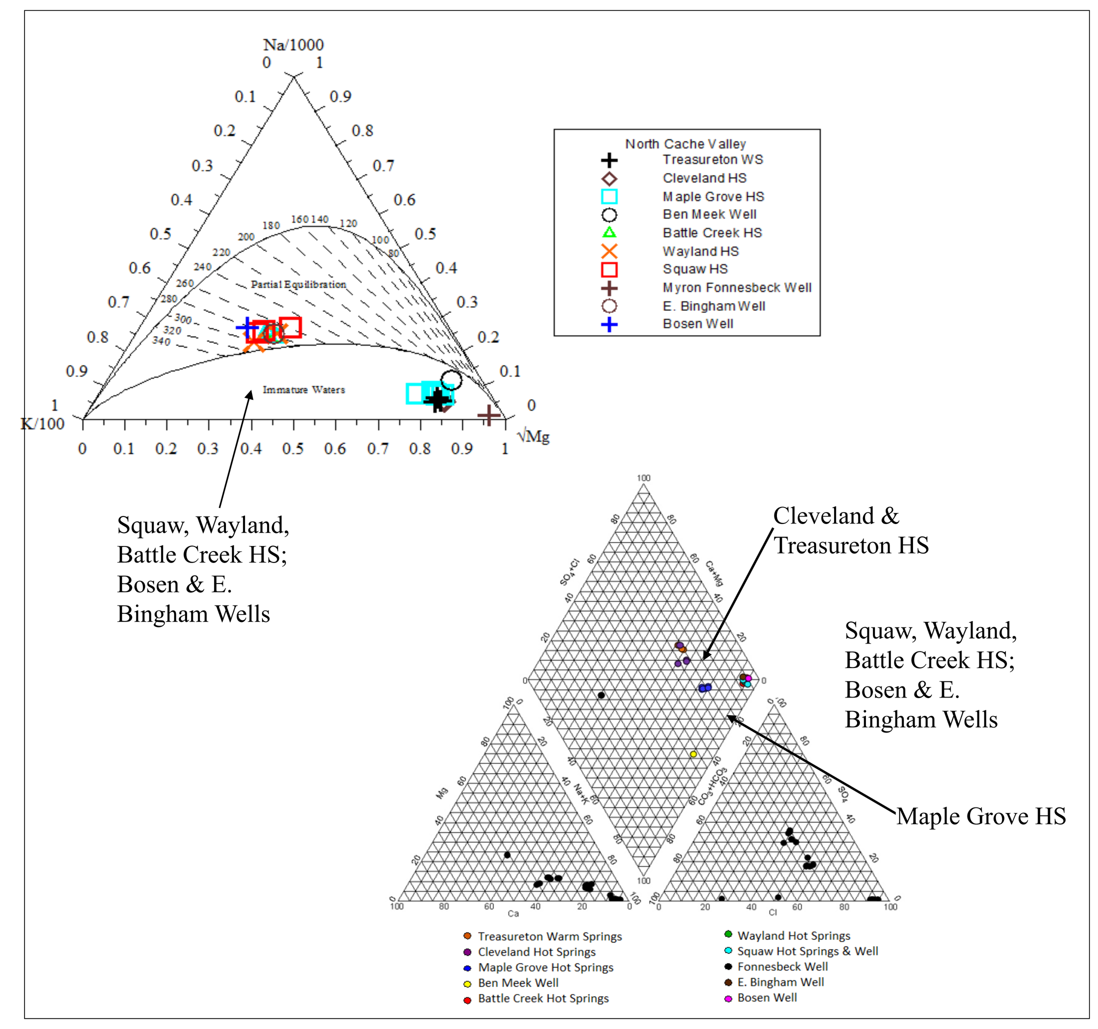

Figure 6. This figure shows water chemistries from NCV plotted on Piper and Giggenbach diagrams. The water chemistries are typical of thermal waters in the Basin. The water chemistry shows a range of immature to partially equilibrated to waters.

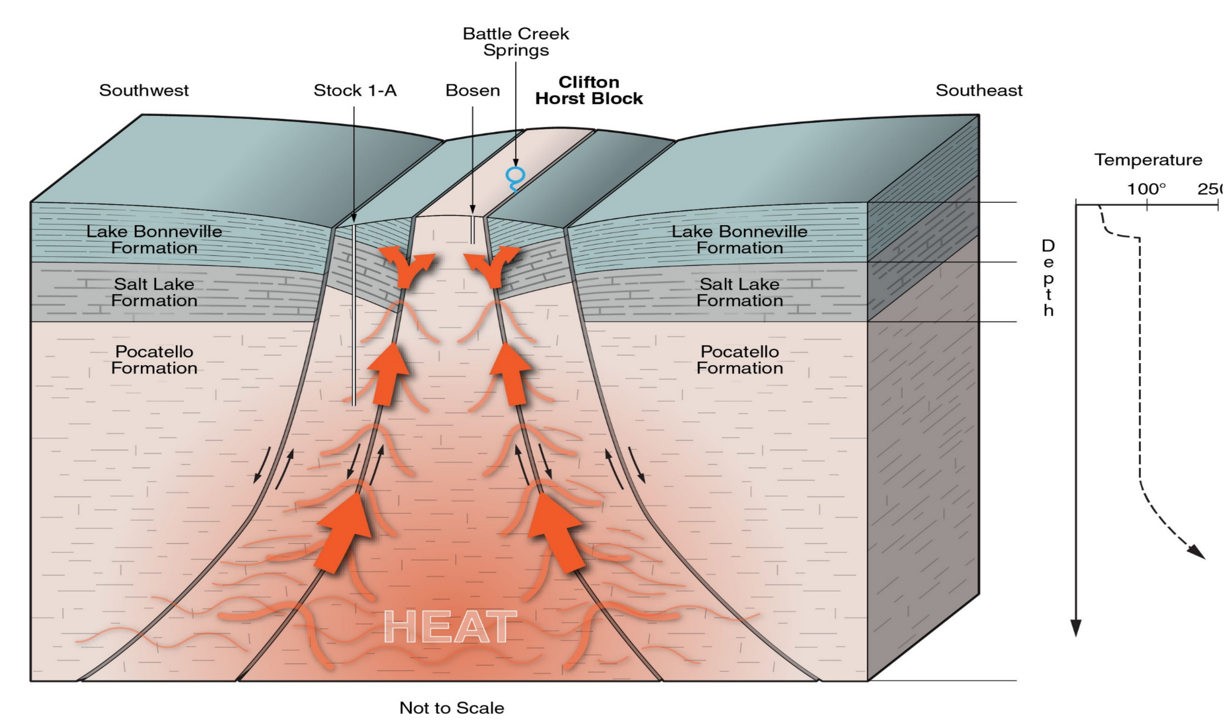

Figure 7. Conceptual geologic cross section of the thermal system of the Preston Prospect. Clifton Hill is depicted as a horst block formed by Basin and Range Extension on the basis of Pre-Cambrian meta sediments exposed at land surface and the thickness of basin fill sediments encountered in the deep exploration wells. Heat is derived from the shallow upper mantle-lower crust boundary typical of the Basin and Range Province. Water is heated at this transitional boundary and travels upward along normal faults bounding Clifton Hill, and spreads laterally in the shallow subsurface, mixing with cooler ground water. The geothermal fluid is encountered at shallow depths (70 to 110 meters) .

Future plans

Collaboration with Idaho State University will yield new Infrared images to be collected via drone recognizance. The data and pictures will be analyzed for heat flow patterns.

A sampling campaign is planned for the summer of 2015. Water samples will be retrieved from wells and springs of the NCV and the Alvord basin to fill gaps in the compiled datasets from historical studies

New Methods Applied

- New geothermometry "Rtest"
- Stable Isotope (He, S, O, C, H)
- Radon (looking for open fractures, finds active fractures)
- Rare earth elements
- Age dating
- Helium
- Geophysical methods
- Air borne thermal imaging
- LiDar

Data Integration & Analysis

- Data Mining
- Analog comparisons
- Chloride flux analysis
- Computation
- Fracture dilation methods
- Native State Modeling
- 3-D geologic modeling (Leap Frog creates grids)
- Visualization CAVE
- Play Fairway Analysis
- Data gap analysis
- Risk reduction assessment

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References

Burkhardt, H. E., Brook, C. A., Smith, F. W., (1980). "Selected Administrative, Land, and Resource Data for Known Geothermal Resource Areas in Arizona, California, Idaho, Nevada, Oregon, and Washington." United States Department of the Interior Geologic Survey, Open-File Report 80-1290

Blackwell, D. D., Richards, M. C., Frone, Z. S., Batir, J. F., Williams, M. A., Ruzo, A. A., Dingwall, R. K., (2011). "SMU Geothermal Laboratory Heat Flow Map of the Conterminous United States, 2011." Supported by Google.org. Available at http://www.smu.edu/geothermal.

Cummings, M.L., St John, A.M., Sturchio, N.C., (1993) "Hydrochemical characterization of the Alvord Basin Geothermal Area, Harney County, Oregon, USA." Proceedings 15th New Zealand Geothermal Workshop, p. 119-124 DeCelles, P. G., (2004). "Late Jurassic to Eocene Evolution of the Cordilleran Thrust Belt and Foreland Basin System, Western U.S.A." American Journal of Science vol 304 p.105-168

Fairley, J.P., Hinds, J.J., (2004) "Rapid transport pathways for geothermal fluids in an active Great Basin fault zone." Geology, v. 32, p. 825-828.

Fairley, J.P., Nicholson, K.N., (2006) "Imaging lateral groundwater flow in the shallow subsurface using stochastic temperature fields," Journal of Hydrology, v. 321, p. 276-285.

Grubbs, K. L., & Van Der Voo, R., (1976). "Structural Deformation of the Idaho-Wyoming Overthrust Belt (U.S.A), as determined by Triassic Paleomagnetism." Tectonophysics, 33, p.321-336McIntyre, J. R., & Koenig, J. B. (1978). "Geology of Sunedco C. H. Stock 1-A Geothermal Test, Franklin County, Idaho."

McIntyre, J. R., & Koenig. J. B. (1980). "Geology and Thermal Regime of Bert Winn #1 Geothermal Test, Franklin County, Idaho

Mitchell, J. C. (1976). "Geothermal Investigations in Idaho, Part 5, Geochemistry and Geologic Setting of the Thermal Waters of the Northern Cache Valley Area, Franklin County, Idaho." Idaho Department of Water Resources Water Information Bulletin 30.

McIntyre, J. R., & Koenig, J. B. (1978). "Geology of Sunedco C. H. Stock 1-A Geothermal Test, Franklin County, Idaho."

McIntyre, J. R., & Koenig. J. B. (1980). "Geology and Thermal Regime of Bert Winn #1 Geothermal Test, Franklin County, Idaho."

Neupane, G., Mattson, E. D., McLing, T. L., Palmer, C. D., Smith, R. W., Wood, T. R., (2014). "Deep Geothermal Reservoir Temperatures in the Eastern Snake River Plain, Idaho using Multicomponent Geothermometry." Proceedings, Thirty-Ninth Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, CA

Nicholson, K.N., Link, K.N., Garringer, L., (2004) Relative ages of the Borax Lake and Mickey geothermal systems, Alvord Basin, Oregon USA: Preliminary evidence from silica phase transitions." Preoceedings 26th New Zealand Geothermal Workshop, p. 40-45.

Palmer, C. D., (2014). "Installation manual for Reservoir Temperature Estimator version 2.5 (RTEst)." Idaho National Laboratory, Idaho Falls, ID

Sbar, M. L., Barazangi, M., Dorman, J., Scholz, C. H., Smith, R. B., (1972). "Tectonics of the Intermountain Seismic Belt, Western United States: Microearthquake Seismicity and Composite Fault Plane Solutions." *Geological Society of America Bulletin* 83, no. 1, p.13-28.

Wood, T. R., Worthing, W., Cannon, C., Palmer, C., Neupane, G., McLing, T. L., Mattson, E., Dobson, P. F., Conrad, M., (2015). "The Preston Geothermal Resources; Renewed Interest in a Known Geothermal Resource Area." Proceedings, Fortieth Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, CA, January 26-28, 2015