Integrated Geologic and Geophysical Approach for Establishing Geothermal Play Fairways and Discovering Blind Geothermal Systems in the Great Basin Region, Western USA: A Progress Report

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Keywords

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ABSTRACT

We have undertaken an integrated geologic, geochemical, and geophysical study of a broad 240-km-wide, 400-km-long transect stretching from west-central to eastern Nevada in the Great Basin region of the western USA. The main goal of this study is to produce a comprehensive geothermal potential map that incorporates up to 11 parameters and identifies geothermal play fairways that represent potential blind or hidden geothermal systems. Our new geothermal potential map incorporates: 1) heat flow; 2) geochemistry from springs and wells; 3) structural setting; 4) recency of faulting; 5) slip rates on Quaternary faults; 6) regional strain rate; 7) slip and dilation tendency on Quaternary faults; 8) seismologic data; 9) gravity data; 10) magnetotelluric data (where available); and 11) seismic reflection data (primarily from the Carson Sink and Steptoe basins). The transect is respectively anchored on its western and eastern ends by regional 3D modeling of the Carson Sink and Steptoe basins, which will provide more detailed geothermal potential maps of these two promising areas. To date, geological, geochemical, and geophysical data sets have been assembled into an ArcGIS platform and combined into a preliminary predictive geothermal play fairway model using various statistical techniques. The fairway model consists of the following components, each of which are represented in grid-cell format in ArcGIS and combined using specified weights and mathematical operators: 1) structural component of permeability; 2) regional-scale component of permeability; 3) combined permeability, and 4) heat source model. The preliminary model demonstrates that the multiple data sets can be successfully combined into a comprehensive favorability map. An initial evaluation using known geothermal systems as benchmarks to test interpretations indicates that the preliminary modeling has done a good job assigning relative ranks of geothermal potential. However, a major challenge is defining logical relative rankings of each parameter and how best to combine the multiple data sets into the geothermal potential/permeability map. Ongoing feedback and data analysis are in use to revise the grouping and weighting of some parameters in order to develop a more robust, optimized, final model. The final product will incorporate more parameters into a geothermal potential map than any previous effort in the region and may serve as a prototype to develop comprehensive geothermal potential maps for other regions.

Introduction

Similar to most hydrocarbon deposits, the bulk of geothermal resources in the Great Basin region lack surface expressions, such as hot springs or fumaroles, and thus lie hidden beneath the surface (Coolbaugh et al., 2007; Williams et al., 2009). In the Great Basin of the western U.S., estimates suggest that ~75% of geothermal resources lack surface expression. Some blind systems in this region (e.g. Desert Peak and Stillwater) are relatively high enthalpy and host power plants. Most of the known blind systems were discovered by accident through regional gradient drilling programs (e.g., Desert Peak; Benoit et al., 1982) or drilling of agricultural (Stillwater) or mineral exploration wells (Blue Mountain).

Considering the probable extent of blind resources, it is imperative that exploration strategies be developed and tested to identify favorable geothermal play fairways (e.g., Walker et al., 2005; Doust, 2010; Siler and Faulds, 2013) as proxies for blind systems. A play fairway analysis defines levels of uncertainty with respect to the presence and utility of geothermal system elements, and translates them into maps over which the most favorable combinations of heat, permeability, and fluid are thought to extend.

Until recently, technology could not identify productive sites and geothermal play fairways with a high degree of certainty without expensive drilling. A critical problem was a lack of sufficient characterization of known systems. However, significant progress has been made in characterizing the geophysical signatures (Wannamaker et al., 2011, 2013) and favorable structural settings of geothermal systems in extensional terranes (Curewitz and Karson, 1997; Faulds et al., 2011, 2013). Geothermal activity correlates with recency of faulting (Bell and Ramelli, 2007), structural setting (Faulds et al., 2011), high strain (Blewitt et al., 2003; Faulds et al., 2012), high slip-dilation tendency on faults (e.g., Morris et al., 1996; Ferrill et al., 1999), geochemical signatures (Shevenell and DeRocher, 2005; Shevenell and Coolbaugh, 2011; Shevenell et al., 2012), low-resistivity (Wannamaker et al., 2011), gravity saddles and terminating gravity gradients (e.g. Saltus and Jachens, 1995; Rowley, 1998), and possibly with a lack of coherent seismic reflections. The key is combining multiple parameters into a comprehensive geothermal potential map that illustrates the most likely locations for geothermal play fairways.

A number of geothermal potential maps have been previously generated using input from predictive physiochemical evidence (Coolbaugh et al., 2005, 2007; Carranza et al., 2008; Williams et al., 2009; Iovenitti et al., 2012; Poux and Suemnicht, 2012). To varying degrees, these studies have implicitly incorporated aspects of play fairway analysis, in the sense that multiple "play fairway" types are acknowledged, and much of the evidential data used in these predictive maps are related to conditions necessary for a geothermal system. Ironically, even though the ultimate purpose of resource potential maps is to identify regions with potential for undiscovered resources, the map-building process has rarely directly incorporated exploration data or information directly pertinent to the ability of systems to remain blind. Nevertheless, Singer (1993) and Coolbaugh et al. (2005, 2007) provided examples in which concepts of degree-of-exploration and *blindness* are included.

To date, Coolbaugh et al. (2005) have produced the most comprehensive geothermal potential map of the Great Basin, incorporating: 1) gravity gradient data, 2) dilational GPS strain rates, 3) upper-crustal temperature gradient, and 4) frequency and magnitude of earthquakes. Considering, however, the significant advancements in the past several years in understanding the structural, geophysical, and geochemical signatures of geothermal systems, as well as the abundance of blind geothermal resources, it is timely to produce a more comprehensive geothermal potential map that incorporates many additional characteristics and a more robust play fairway analysis.

We have therefore embarked on an integrated geologic and geophysical study of a broad 240-km-wide, 400-km-long transect stretching from west-central to eastern Nevada in the Great Basin region of the western USA (Fig. 1). Due to its high heat and relatively high extensional to transtensional strain rates, the Great Basin region is one of the largest geothermal provinces on Earth. We are therefore analyzing a broad transect across this region and applying the most innovative technologies to locate potential undiscovered blind resources.

The study area spans a progressive westward increase in strain across the Great Basin of Nevada (e.g., Kreemer et al., 2012). It is anchored by more thorough analysis of two large basins on the western and eastern ends of the transect (Fig. 1), the Carson Sink and Steptoe basins, respectively. The high geothermal potential of the western part of the study area (Carson Sink region) has long been known, but this large basin (e.g. northern part) may contain several additional blind systems. Further study of the Carson Sink is also warranted by new detailed gravity and available seismic reflection data. Although both eastern and central Nevada have relatively low strain rates, they may be underappreciated in terms of geothermal potential, as evidenced by robust high enthalpy systems at Beowawe and McGinness Hills, which host 18 MW and 72 MW geothermal power plants, respectively. Notably, McGinness Hills is a blind system, with no surface hot springs or fumaroles. The Steptoe basin on the eastern end of the transect (Fig. 1) is in a relatively under-explored region that contains significant potential for both hydrothermal and sedimentary hosted geothermal systems (e.g., Allis et al., 2013; Hinz et al., 2015). Generating a detailed geothermal potential map of this entire region may serve as a prototype for producing similar maps in other extensional settings and eventually completing a detailed map of the entire Great Basin.

Approach

The main principles pursued in this project involve characterization of geothermal play fairways (utilizing multiple geologic, geochemical, and geophysical techniques) and application of geostatistical analysis, including weights of evidence and other methods to the various parameters. The main goals are to define the most favorable settings for geothermal activity (i.e., geothermal play fairways), produce detailed geothermal potential maps, and identify potential blind systems. Our approach integrates conventional methods, such as analysis of structural settings and geochemistry of fluids, with innovative techniques, including slip-dilation tendency analysis, 3D inversion of MT data, and 3D modeling. This project marks the first attempt to combine as many as 11 parameters into a detailed geothermal potential map and robust play fairway analysis.

This project focuses on fault-controlled geothermal play fairways, which are the primary reservoirs for geothermal systems in the Great Basin (e.g., Benoit et al., 1982; Blackwell et al., 1999). Elevated permeability associated with fault zones provides pathways for fluid circulation (e.g., Sibson, 1996). Fault-controlled geothermal systems are associated with specific structural settings, as well as geochemical and geophysical anomalies. For example, most of the known geothermal systems are associated with high density faulting at fault intersection/interaction areas, such as horse-tailing fault terminations, step-overs or relay ramps, fault intersections, and accommodation zones (Curewitz and Karson, 1997; Faulds et al., 2006, 2011; Faulds and Hinz, 2015; Hinz et al., 2011).

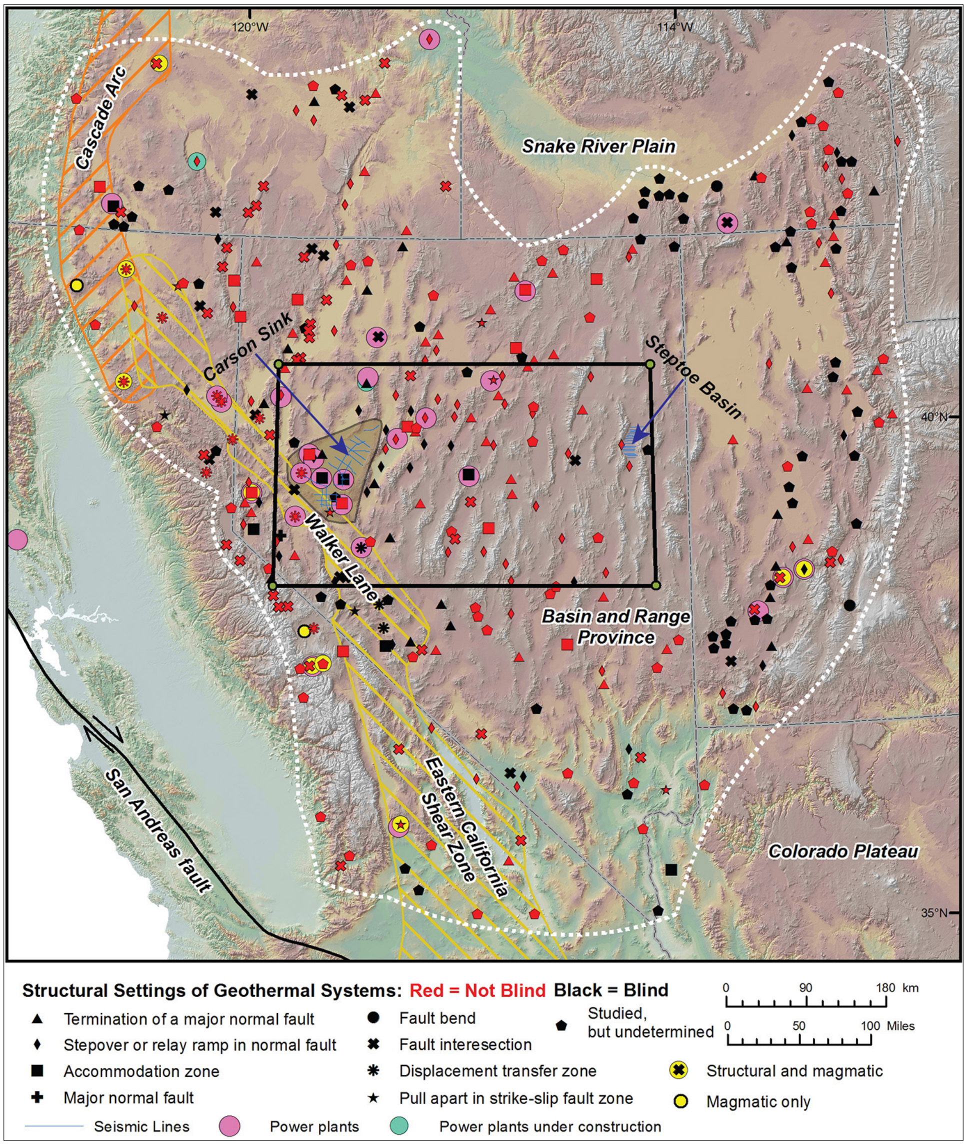

Figure 1. Structural settings of known geothermal systems (blind and not blind) in the Great Basin region. Black box outlines the study area, which form a continuous transect across the Great Basin region in Nevada. Brown shaded area outlines the Carson Sink area. Thin blue lines show the selected seismic reflection profiles in the Carson Sink and Steptoe basins.

Selecting the best sites for drilling and successful development of these systems relies on accurately defining permeable zones in 3D space. However, no single tool can define the detailed structural framework of a geothermal area and fault segments that host fluids (e.g., Siler et al., 2012; Hinz et al., 2013). We have therefore taken a multi-disciplinary approach that involves multiple geologic and geophysical techniques aimed at characterizing the signatures of geothermal systems. Specific methods include: a) Geologic data review and interpretations, incorporating geologic maps, well data, Quaternary fault data (recency of faulting and slip rates), and heat flow; b) geophysical data review and interpretations, including available seismic reflection, gravity, and MT data; c) geochemical review and interpretations; d) geodetic review and interpretations; e) analysis of structural settings; f) slip and dilation tendency analysis of faults; g) GIS geodatabase compilations; h) 3D modeling of two basins (Carson Sink and Steptoe Valley) on the west and east ends of the transect; and i) quantitative geostatistical analysis of geothermal potential that integrates multiple parameters into a single geothermal potential map. Our new geothermal potential map will incorporate: 1) heat flow; 2) geochemistry from springs and wells; 3) structural setting; 4) recency of faulting; 5) slip rates on Quaternary faults; 6) regional strain rate; 7) slip and dilation tendency; 8) seismologic data; 9) gravity data; 10) magnetotelluric (MT) data (where available); and 11) seismic reflection data (primarily from the Carson Sink and Steptoe basins).

Although this project focuses on fault-controlled hydrothermal systems, the findings will also be relevant to sedimentary-hosted and EGS systems. For example, sedimentary-hosted systems may be particularly robust in the eastern study area due to permeable carbonate basement aquifers and relatively thick basin-fill sediments in the interior-drained basins (Allis et al., 2013). However, fault patterns and the overall basin architecture probably control the geothermal upwellings and major intra-basin reservoirs. Thus, we will estimate the potential of such systems for those basins, where sufficient geologic, geochemical, geophysical, and well data exist for evaluation. In addition, the favorability for EGS development relies on the structural and stratigraphic framework. Thus, our geothermal potential maps can be related directly to potential EGS development, including enhancement of operating geothermal power plants through stimulation of peripheral wells (e.g., Desert Peak; Chabora et al., 2012).

Initial Results – Preliminary Geothermal Potential Map

Geological, geochemical, and geophysical data sets were assembled in ArcGIS and combined into a preliminary predictive geothermal play fairway model using various statistical techniques.

Data Sets

Geologic data: Geologic maps, well and spring data, locations and slip rates on Quaternary faults, heat flow and temperature gradient data, regional stress data (e.g., Heidbach et al., 2008), and known geothermal systems were compiled for the study area. In addition, ~200 favorable structural settings (e.g. fault stepovers, terminations, accommodation zones, and fault intersections) have thus far been identified and rated based on certainty and complexity (more complex settings=higher rating). **Geochemical data**: Geothermometer calculations were compiled for 880 cold and 987 thermal waters. Quality factors were assigned to each analysis based on charge balance (20% weight), Na-K-Ca minus quartz geothermometer temperatures (30%), maturity indices (20%), and measured temperatures (30%). These factors were used to weight the reliability of geothermometer estimates in the statistical modeling. **Gravity data**: Publically available gravity data (44,400 stations) were compiled, integrated, and edited for consistency. Contour maps showing isostatic anomalies (standard Bouguer with isostatic correction), vertical and horizontal gradient derivatives, and basin depths were completed. Our initial analysis simply rated horizontal gravity gradients as a proxy for identifying major faults. **Seismic reflection data**: Available seismic reflection profiles were reviewed, with ~425 miles of profiles selected for analysis, primarily in the Carson Sink and Steptoe basins. These data will be used to identify favorable structural settings hidden beneath large composite basins and possibly to identify a seismic reflection signature for some of these settings. **MT data**: Available MT data, including an E-W transect of ~200 stations and 3D distributions at McGinness Hills system (100 sites) and the NW part of the study area, (131 sites) were integrated. Both shallow and deep MT anomalies will be used to gauge geothermal potential. These data were not incorporated into the preliminary model. **Seismologic data**: Earthquake locations were compiled from available catalogues through October 2014. Because the density of seismic stations varies across the study area, the lower threshold of well-located earthquakes also varies. **Geodetic data**: The contoured second invariant and principal strain rate axes (normalized) were calculated from 247 GPS stations. Higher strain rates were presumed to be favorable for geothermal activity (Blewitt et al., 2003; Faulds et al., 2012). **Slip-dilation tendency analysis**: Slip and dilation tendency were calculated for Quaternary faults using principal stresses derived from published borehole breakout data, earthquake focal mechanisms, and stress-inversions from fault kinematic data. A value for distance to the nearest stress measurement was also generated to rate uncertainty of the calculations.

Preliminary Model

Utilizing the play fairway approach, a preliminary predictive model in the form of a geothermal potential map was produced utilizing most of the data sets. Two key geological factors (Fugelli and Olsen, 2005) or principal hierarchical tiers (Doust, 2010) were considered: permeability and heat. The most critical of these is permeability. Viable production from geothermal reservoirs requires relatively high flow rates from wells, which in turn requires relatively high host rock permeabilities. The spatial distribution of permeability is extremely variable (over multiple magnitudes) at the depths of 0.5 to 3 km, where reservoir production typically occurs, and it is challenging to model. Consequently, permeability is considered the most important component and has received the most attention in this model.

The availability of heat, the second key factor, also plays a role. Temperatures at the depth of a potential reservoir have to be sufficiently high (typically >130°C) to provide the enthalpies necessary for economic energy extraction. Background temperature gradients in the Great Basin, commonly ranging from 25 to 50°C/km, are anomalously high compared to temperature gradients in most continental cratonic areas. For this reason, heat is not considered as critical a factor as permeability. Nonetheless, some parts of the study area, especially deeper fault-controlled valleys (e.g., Steptoe Valley, eastern Nevada) are known to have especially high temperature gradients (~50°C/km) due to the presence of thick accumulations of relatively low-thermal-conductivity sediments. Areas where economic temperatures are attained at shallower depths have an advantage over areas where the same temperatures reside at greater depths, because higher pressures at depth generally work to close fractures. For this reason, availability of heat was modeled as a second factor, even though it does not vary from place to place nearly as much as permeability.

Permeability was combined with regional heat flow to define a preliminary fairway. This fairway was subsequently modified to take into consideration the fact that past geothermal exploration is unevenly distributed. In addition, some portions of the fairway are considered more capable of hosting hidden geothermal systems than others, depending, for example, on the depth of the water table. Consequently, a degree-of-exploration model was built that includes components of past exploration, as well as components modeling the ability of a geothermal system to remain concealed. The degree-of-exploration model was intersected with the fairway model to highlight unexplored areas where the potential for blind systems is good.

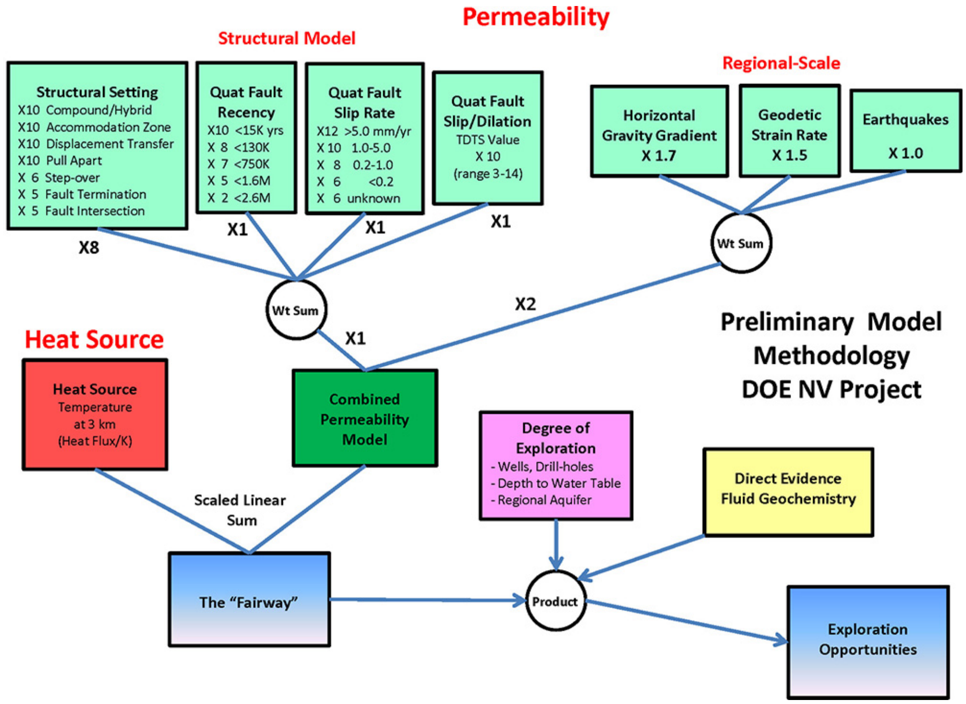

Figure 2. General methodology and weighting parameters for various components of the preliminary model for this project.

The favorability model can be further modified to include direct evidence of geothermal activity. Such evidence includes the presence of active thermal manifestations and associated geochemistry and geothermometry. An initial predictive "direct evidence" map was constructed using a systematic compilation of spring and well temperatures and geothermometry. Though this map was not directly incorporated in the preliminary model discussed herein, it will be integrated into the final predictive model of "exploration opportunities" (Fig. 2) near the end of this project.

Permeability: The permeability model consists of two components; a structural model and a regional-scale model. The structural model predicts geothermal potential on the basis of local structural setting and fault characteristics, whereas the regional-scale model evaluates more regionally distributed parameters including gravity gradient, strain rate, and earthquake frequency (Fig. 2).

Structural Component of Permeability: The structural component of permeability consisted of several major parameters. First, a series of ellipses (Fig. 3) defining favorable structural settings was converted to grid format, and each setting was

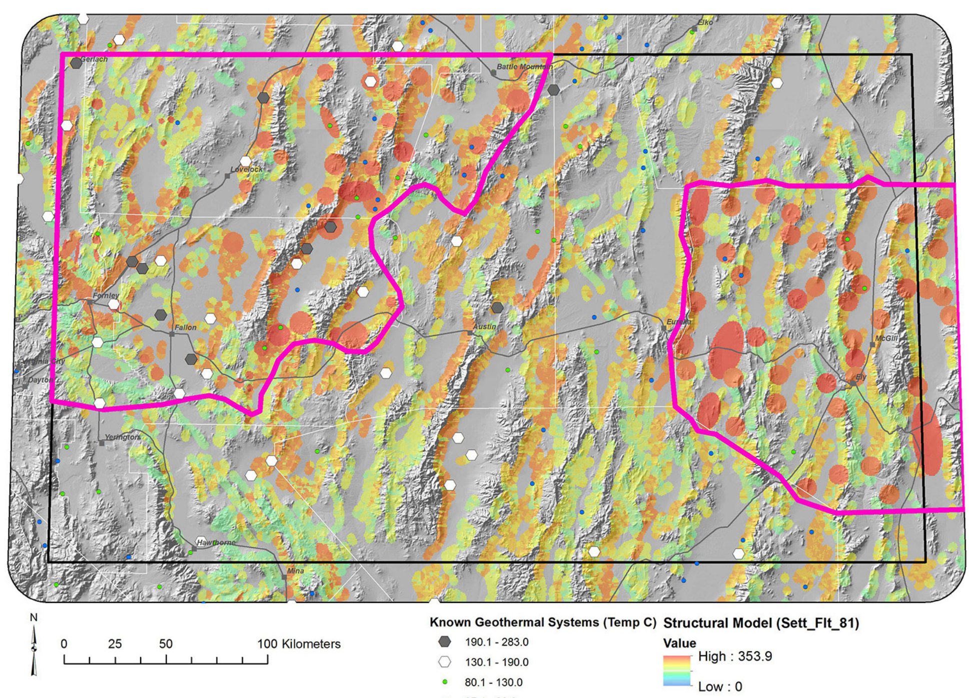

Figure 3. The structural component of permeability consisting of favorable structural settings and age, slip rate, and slip/dilation tendency on Quaternary faults. For this preliminary model, the value for structural setting was multiplied by 8, fault recency by 1.0, fault slip rate by 1.0, and slip/dilation tendency by 1.0. A 2-km buffer was applied to Quaternary faults. Purple line shows areas where favorable structural settings have been defined to date.

assigned favorability weights ranging from 5 to 10 based on certainty of the setting and complexity, with greater certainty and great structural complexity receiving the higher ratings (Fig. 2). Secondly, a Quaternary fault database of line segments representing faults was coded for three parameters: 1) recency of faulting, 2) slip rate, and 3) slip/dilation tendency. Each of these parameters received weights according to degree of recency, slip rate, and slip/dilation tendency, and each of the three parameters ranged up to 10 (Fig. 2). The three weighted parameters were then combined into a single index for each fault segment. A 2-km buffer was used to convert the fault line segments into a grid map. The structural setting grid layer was multiplied by a factor of 8 before adding it to the Quaternary fault grid layer to produce a weighted sum 'structural component of permeability' (Fig. 3).

Regional Component of Permeability: The regional-scale component of the permeability model consists of three raster layers representing earthquakes, geodetic strain rate, and horizontal gravity gradient (Fig. 4). For the preliminary model, only those earthquakes with magnitudes sufficiently large enough that they could be detected anywhere in the study area with the array in place at the time of the earthquake were included. The threshold magnitude used was 4.8 or higher prior to 1970. After 1970, the threshold magnitude was 4.0. All earthquakes (>99% of the database) not meeting these criteria were not used in calculations. A grid layer was created, and within each cell in the model, the total number of earthquakes occurring within a 20 km radius was summed. This constitutes the earthquake predictive layer, and values ranged from 0 to 37. For the geodetic strain rate layer, the second invariant of strain was reclassified into a scale from 1 to 7 using an approximate log-normal conversion. The horizontal gravity gradient layer was supplied in grid format and had a scale ranging from 0 to 7.6. After normalizing the range of data for all three regional data layers, they were weighted with the following scheme: a weight of 1 for earthquakes, a weight of 1.7 for the horizontal gravity gradient, and a weight of 1.5 for the strain grid. These weights are proportional to the weights-of-evidence contrast statistics generated for these three layers in a previous weights-of-evidence model (Coolbaugh et al., 2007) constructed for the state of Nevada. The larger area of the previous model facilitates the use of data-driven statistics, which provide relative measures of the predictive abilities of individual layers. After each grid was multiplied by its respective weight, the three grids were added together to produce a single weighted-sum for the regional scale model (Fig. 4).

Combined Permeability Model: For the combined permeability model, the regional-scale model grid was weighted (multiplied) by a factor of 2 before adding it to the structural model grid to produce an overall weighted sum, which we refer to as the 'combined permeability model'. The magnitude of the relative weight was determined visually to provide appropriate expression of both components. In the final model, a more quantitative, statistically supported weight determination will be employed.

Heat Source: For the heat source model, a derivative map representing temperatures at a depth of 3 km was used (Fig. 5). This derivative map was generated through collaboration between Southern Methodist University Geothermal Laboratory (David Blackwell; e.g., Blackwell et al., 2010) and the Great Basin Center for Geothermal Energy approximately 10 years ago during production of a Great Basin geothermal potential map (Coolbaugh et al., 2005). This map differs from most other heat flow type maps of the western USA in that it carries sufficient detail to distinguish higher predicted temperatures at 3 km beneath thick accumulations of young sediments with low thermal conductivity in Neogene basins from lower predicted temperatures at 3 km beneath mountain ranges, where thermal conductivities are higher.

Generation of Fairway Model: The fairway grid model was generated using a scaled linear sum of the combined permeability model and the

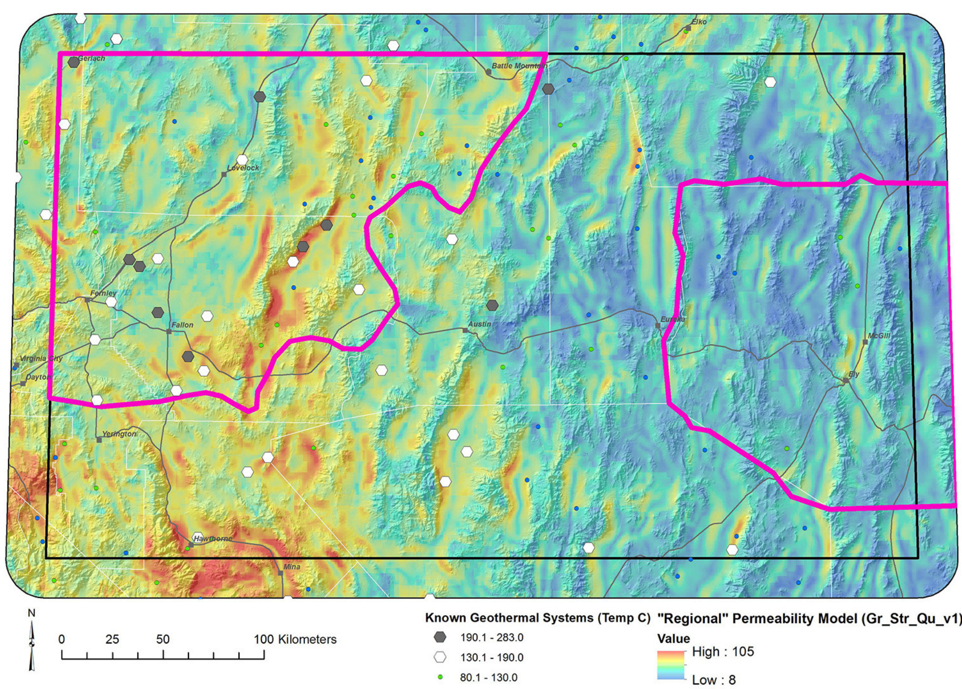

Figure 4. The regional-scale component of permeability consisting of three raster layers representing earthquakes, geodetic strain rate, and horizontal gravity gradient. For the preliminary model, the value for horizontal gravity gradient were multiplied by 1.7, geodetic strain by 1.5, and earthquakes by 1.0.

heat source model (Fig. 6). The equation used is: combined permeability model + 3.2 * heat source model. Although the equation would suggest a higher weighting for heat than for permeability, in actuality, the permeability layer carries a much greater weight. The multiplier of 3.2 in this case only serves to rescale the data. The relative weights were determined from examination of 2-D scatter plots of the distribution of heat source values and permeability model values throughout the study area. The scaling represents a linear index that optimizes the discrimination between indices of permeability and heat associated with known geothermal systems and those areas without such systems.

Degree-of-Exploration Model: In the preliminary model, a degree-of-exploration parameter initially constructed by Coolbaugh et al. (2007) for Nevada was incorporated. The grid layer contains values ranging from near 0 to near 1, qualitatively representing the degree-of-exploration where 0 = no exploration (and thus with some potential for blind systems) and 1 = 100% exploration (where any geothermal system, if it exists, would already be found). Information used to compile the degree-of-exploration model included location, type, and depth of drill-holes and wells, depth of the water table, and presence or absence of a regional carbonate aquifer. The degree-of-exploration model was intersected with the fairway model to highlight areas where undiscovered and/or blind geothermal systems are most likely to be found within the study area (Fig. 7).

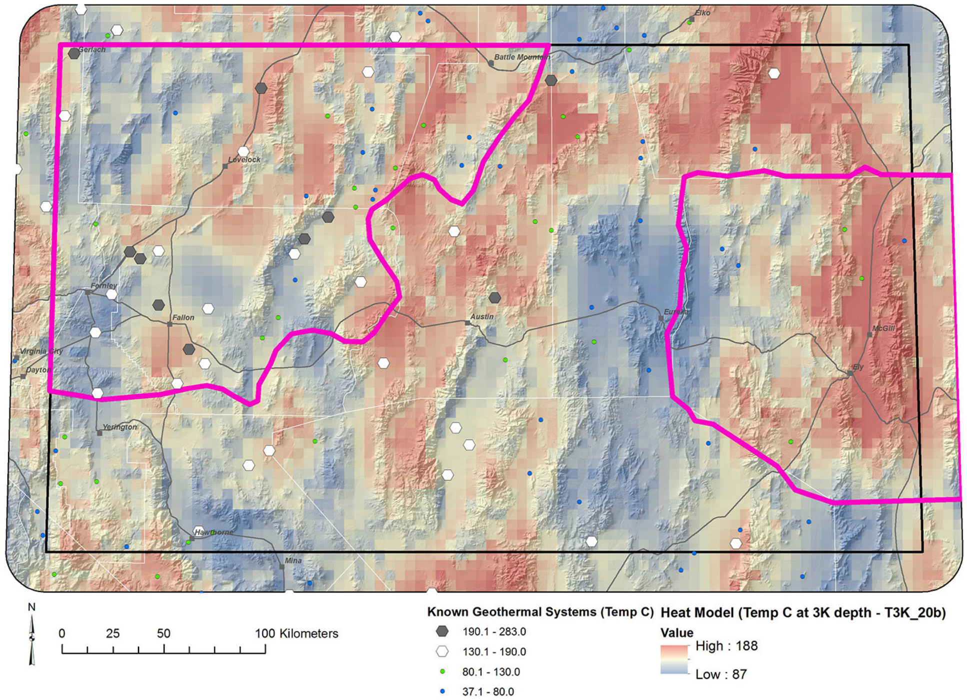

Figure 5. The heat source model is a derivative map representing temperatures at a depth of 3 km. This derivative map was generated through collaboration with the Southern Methodist University Geothermal Laboratory (David Blackwell).

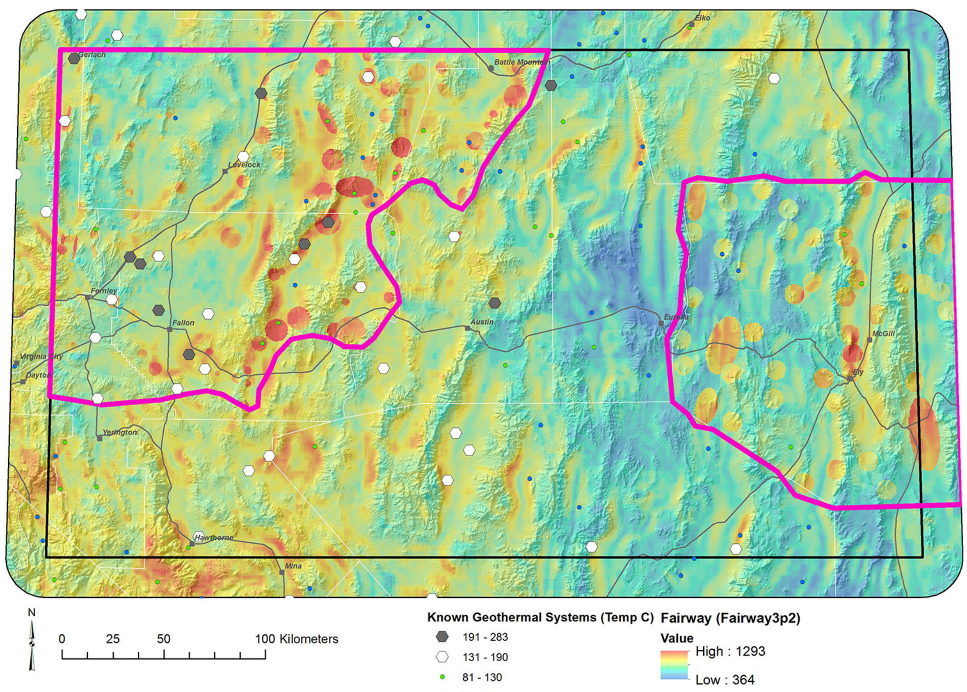

Figure 6. The overall fairway grid model was generated using a scaled linear sum of the combined permeability model and the heat source model (Fig. 2). The equation used is: combined permeability model + 3.2 * heat source model. Purple boundary is the portion of the study area for which structural settings have been defined to date.

Discussion and Conclusions

Multiple geologic, geochemical, and geophysical databases were compiled to produce a preliminary geothermal potential map for a broad transect across the Great Basin region (Figs. 1 and 6). The preliminary model demonstrated that the multiple data sets can be successfully combined into a comprehensive favorability map. However, a major challenge is defining logical relative rankings of each parameter and how best to combine the multiple data sets into the geothermal potential/permeability map. This is partly an iterative process, as data are evaluated with respect to known geothermal systems with high permeability and successful development, which serve as benchmarks with which to evaluate the results. Based on initial feedback, we are in the process of refining the grouping and weighting of some parameters.

Key observations include:

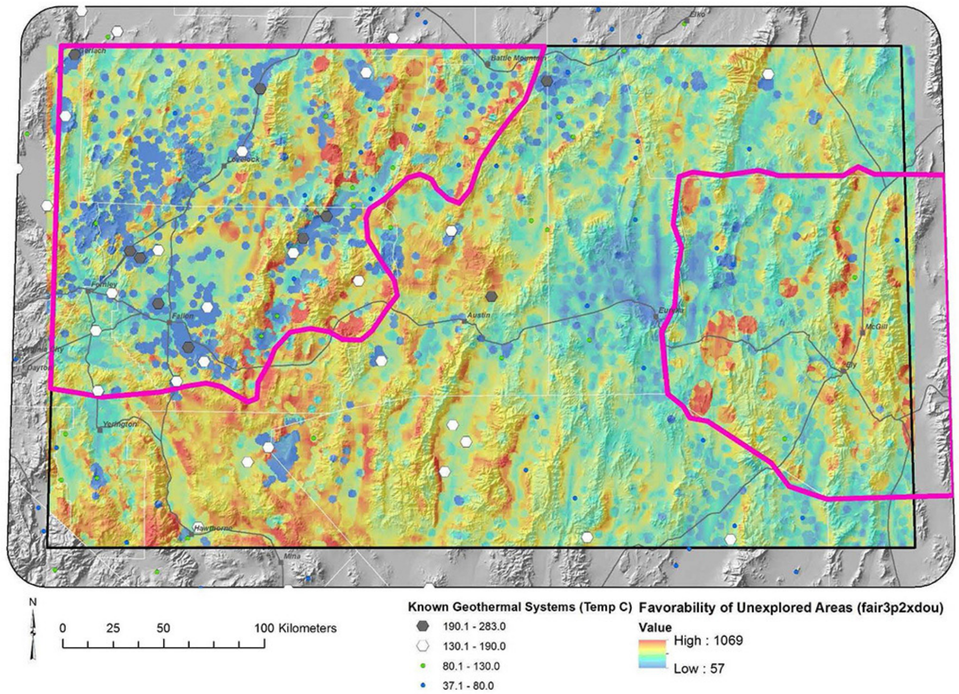

Figure 7. The fairway grid model (Fig. 6) after intersection with the degree-of-exploration model. Warmer colors highlight areas of the fairway that are relatively unexplored and/or have potential for hosting blind geothermal systems. Purple boundary is the portion of the study area for which structural settings have been defined to date. Known geothermal systems (pentagons) lie within explored areas.

- Large horizontal gravity gradients marking major faults are not favorable for geothermal activity, but the ends or irregularities in such gradients correlate with geothermal systems in fault tips or steopovers.
- The density of earthquakes rather than magnitude appears to correlate with geothermal systems.
- Higher strain rates clearly correlate with a greater density of high-enthalpy systems.
- Quaternary faults are critical for higher enthalpy (>150˚C) geothermal systems and thus recency of faulting should be weighted more in the final modeling for the geothermal potential map.
- Because major faults are not conducive for geothermal activity, high slip rates on Quaternary faults may indicate low geothermal potential on main fault segments, but high potential on associated discontinuities in such fault systems, such as stepovers, terminations, and intersections.
- Each favorable structural setting should be ranked on the basis of recency of faulting on Quaternary faults that are linked to that particular setting.
- Initial analysis of the seismic reflection profiles indicates favorable structural settings in the Carson Sink and Steptoe basins, including heretofore unrecognized fault stepovers, terminations, and accommodation zones buried beneath these composite basins.
- The marketability of prospects should also be constrained by distance to transmission and population density, which affect the viability of electricity production and/or direct use.

Ultimately, our multi-disciplinary analysis will combine multiple data sets into a cohesive model of appropriately weighted individual data types to predict permeability and geothermal potential. This will yield a detailed geothermal potential map illustrating geothermal play fairways, which will reduce the uncertainty in prospecting for blind geothermal systems across a wide swath of the Great Basin. This will be the most detailed geothermal potential map produced for this region to date, incorporating more parameters than any other map. It may therefore serve as a prototype for producing geothermal potential maps for the entire Great Basin, as well as other geothermal regions. The accompanying 3D models of two large basins at both ends of the transect will provide a template for producing even more detailed geothermal potential maps, further reducing the risks of exploration and development of blind systems in particularly promising areas. It is also noteworthy that application of play fairway analysis and identification of potential blind geothermal systems over large areas are generally beyond the scope of individual geothermal companies. These types of studies and resource assessments are well suited for state geological surveys (like NBMG), which serve as regional repositories for geologic and geophysical data (e.g. well logs and cuttings) and whose mission is to publish information for the greater public good. Ultimately, this project may help to stimulate a resurgence in greenfield exploration and facilitate competitive geothermal development of new blind geothermal resources in the Great Basin, while also significantly advancing the discipline of geothermal play fairway analysis.

Acknowledgments

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