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Geothermal Play Fairway Projects Initiated by the U.S. Department of Energy

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ABSTRACT

A play fairway is the area in a basin or region where examples of an individual play type are projected to exist and is defined by the geologic characteristics of the basin and of the play type. A play fairway analysis incorporates basin-wide evidence for the occurrence of the requisite geological factors of a particular play type, and plots the probability of finding the play over the entire area of study. This allows for rigorous quantification of exploration risk; areas with the highest probability of success are highlighted as fairways on the resulting maps and are the main focus in subsequent stages of exploration. Borrowing the terminology and assessment tools from the oil and gas industry, U.S. Department of Energy Geothermal Technologies Office (GTO) has funded research to further develop this technique for use in identifying and exploring opportunities for potential geothermal systems. The Play Fairway Analysis Funding Opportunity Announcement was released in 2014. Eleven projects were competitively selected.

Effective oil and gas play fairway analysis extends beyond the simple hydrocarbon documentation, and the geothermal analysis and fairway mapping now underway extends beyond observation of subsurface temperatures. These projects will develop geothermal fairway maps utilizing a wide range of data. Observation of subsurface temperatures and structural and tectonic settings, as well as chemical and isotopic data, rock mechanics, and hydrologic and basin history will contribute to the analyses. This paper reviews the intention of the GTO announcement and introduces the eleven projects that are now underway.

1. INTRODUCTION

A major barrier to the development of the large geothermal resources in the United States is the difficulty in locating blind hydrothermal systems, along with the great expense of exploratory drilling. DOE Geothermal Technologies office has made a priority of advancing the state of the art in exploring for blind hydrothermal systems, and key among these technologies is the concept of play fairway analysis. Already successfully used in the oil and gas sector, play fairway analysis can be a key tool for decision making in any exploration project. This paper describes DOE's current efforts in adapting play fairway methods for use in geothermal exploration, with the ultimate goal of quantifying and reducing risk in geothermal exploration.

In oil and gas parlance, a petroleum 'play' is a group of fields or prospects that are controlled by the same set of geological circumstances (Stoneley, 1995). Similarly, a geothermal play would be a set of potential geothermal systems sharing the same geologic setting or origins. A play fairway then is the portion of a study area with a high probability of encountering a particular play, based on high confidence in the presence of the geologic factors required for the formation of the play. In hydrocarbon exploration, those factors include reservoir rock, source rock, a trap, etc. A conventional hydrocarbon play analysis might follow a process similar to the steps shown in Figure 1 to determine where the fairways are located.

To determine the geologic factors and play types that will be considered in a geothermal play analysis, it is useful to think in terms of geothermal occurrence models. While early efforts in geothermal exploration focused mostly on heat flow, much work has been done in recent years developing occurrence models that could be a valid basis for play fairway analysis (e.g., Carranza and others, 2008; Siler and Faulds, 2013; King and Metcalfe, 2013). A well-considered occurrence model coupled with adequate data and a rigorous statistical treatment can provide for a complete systematic approach for early stage geothermal exploration.

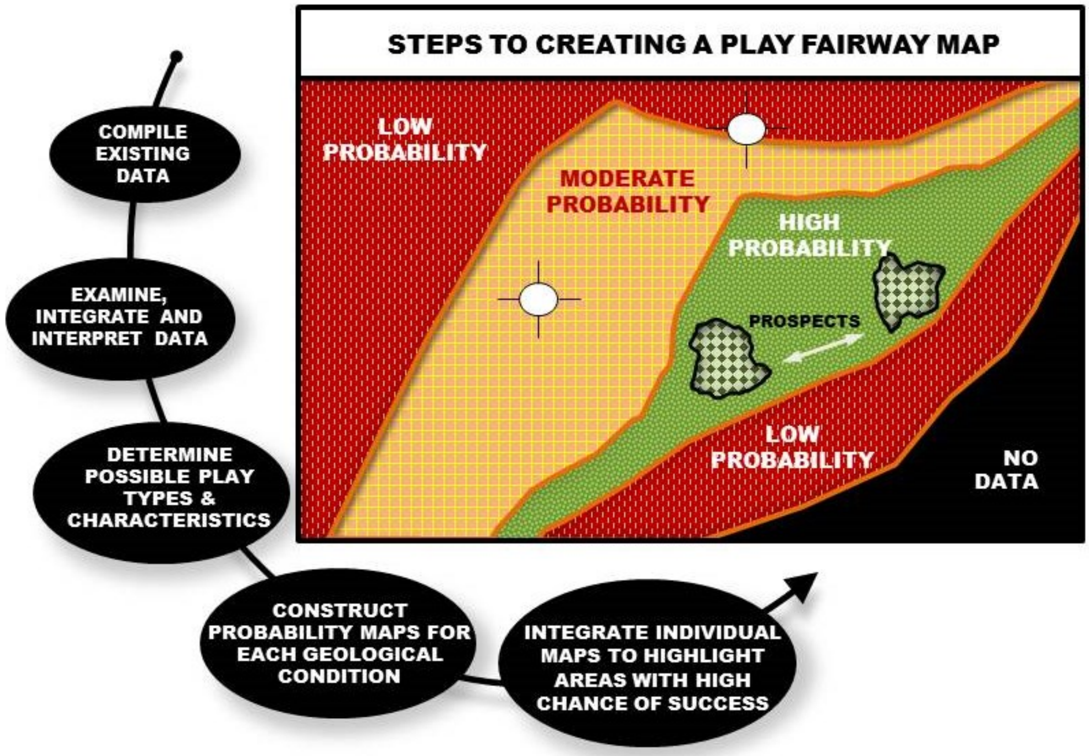

Figure 1: General process of creating a play fairway map. Note that critical to the process is determining the type or types of possible resources in the region of study. Not all the individual probability maps might be used in the creation of each play fairway map.

2. FUNDING OPPORTUNITY ANNOUNCEMENT (FOA) PROCESS

The primary goals for the Funding Opportunity were to demonstrate methods for rigorously quantifying project risk, thereby aiding in project finance, and to high-grade potential drilling areas to reduce the number of unsuccessful wells that are drilled. Applications were solicited for Phase 1 projects that:

- Focus on under- or unexplored regions (play analysis is early-stage exploration, and not intended to step out from existing known resources)
- Are at a basin- or regional scale
- Consider a wide range of possible geothermal resources, including traditional hydrothermal, blind hydrothermal, EGS, and low-temperature geothermal resources
- Apply innovative analysis methods to extract new value from existing public and/or private data.
- Develop methodologies to couple multiple data types
- If an area looks prospective, will develop a clear plan to further characterize the geothermal resource in later project phases

A phased project approach was adopted per usual GTO policies; Phase 1 will run from 9/30/2014 to 10/31/2015. Restrictions on projects for Phase 1 include a cap of $500,000 DOE share, prohibition on field collection of data (Phase 1 is a desktop analysis only) and time limit of 13 months. Project teams will deliver an exploration plan at the end of Phase 1 including all recommendations for future work. A competitive downselect process will follow and a subset of projects will continue on to Phase 2 (subject to budgetary constraints).

2.1 Response

The FOA received 48 concept papers; 35 of these were encouraged to submit full applications, and in the end 33 full applications were submitted. For simplicity in the review process, they were divided roughly by geography into four regions, and four panels of independent reviewers were assembled to complete the reviews. Eleven applications were selected for awards in the form of cooperative agreements.

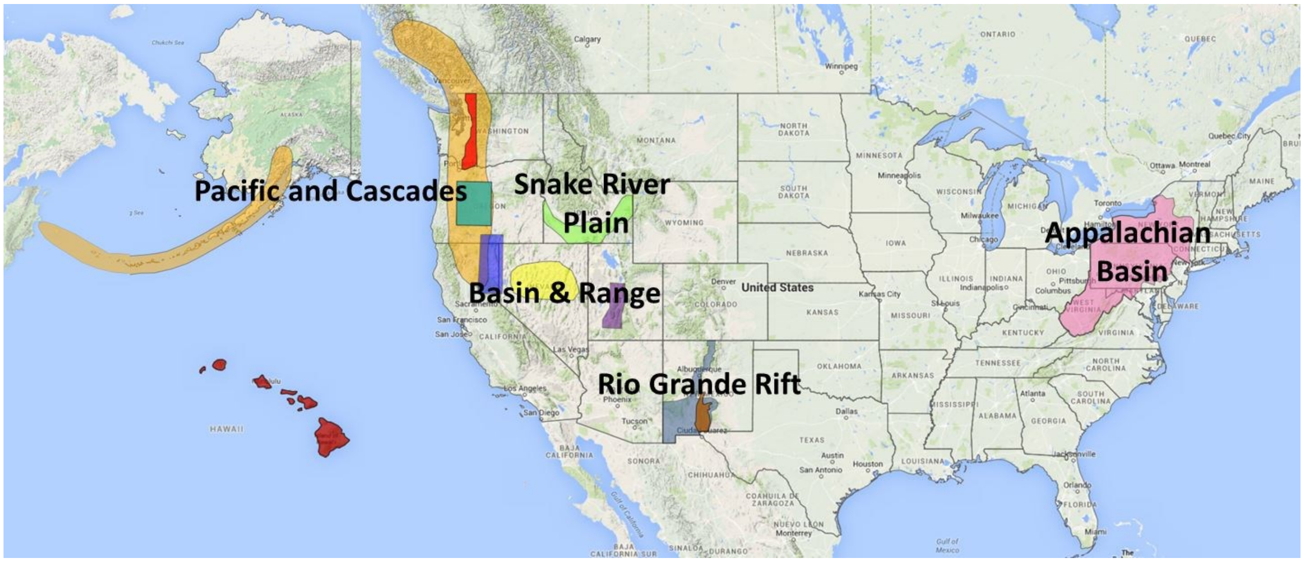

Figure 2: Areas of the United States being studied through this FOA by Play Fairway Analysis.

2.2 Reproducible Research

To maximize the value obtained from these projects, some new requirements are in place in the cooperative agreements. As part of the final technical report, principal investigators will deliver the complete set of files used to generate the results in an effort to make the work publically available in a format that allows other analysts to easily verify, modify, and extend the work. This will be accomplished through the use of online data repositories (NGDS), scientific notebooks, and/ or companion websites.

The National Geothermal Data System (NGDS) is a primary source of input data for many of the analyses described in this paper. Furthermore, any data obtained from other sources will be added to NGDS by the end of Phase 1 (subject to copyright restrictions). To enhance the ability of independent analysts to reuse the work, the use of scientific notebooks and related software by the investigators is strongly encouraged (e.g. Matlab, IPython). These tools make the methods and algorithms used in an analysis extremely transparent to the reader. They also allow the interested reader to easily adjust input parameters and re-run the analysis. Several of the project teams are building companion websites to share the work; others may be hosted by the DOE. It is expected that these steps will enhance interest in the results, and that analysts from private industry will download and interact with the models being developed.

3. PROJECT HIGHLIGHTS

The following table and paragraphs provide details from the eleven project teams that were selected.

Table 1. Summary of projects by region, organization, PI, and funding breakdown.

Project Title	Region	Organization	Principal Investigator	Awardee Share	DOE Share
Low-Temperature Geothermal Play Fairway Analysis for the Appalachian Basin	Appalachain Basin	Cornell University	Teresa Jordan	$45,322	$407,906
Discovering Blind Geothermal Systems in the Great Basin Region: An Integrated Geologic and Geophysical Approach for Establishing Geothermal Play Fairways	Basin and Range	Nevada Bureau of Mines and Geology	Jim Faulds	$57,901	$499,992
Geothermal Play Fairway Analysis of Potential Geothermal Resources in NE California, NW Nevada, and Southern Oregon: A Transition Between Extension-Hosted and Volcanically-Hosted Geothermal Fields.	Basin and Range	University of California, Davis	Jim McClain	$42,707	$378,388
Structurally Controlled Geothermal Systems in the Eastern Great Basin Extensional Regime, Utah	Basin and Range	University of Utah	Phil Wannamaker	$52,487	$472,387
Geothermal Potential of the Cascade and Aleutian Arcs with Ranking of Individual Volcanic Centers for their Potential to Host Electricity-Grade Reservoirs	Pacific and Cascades	ATLAS Geosciences, Inc	Lisa Shevenell	$68,424	$274,840
Geothermal Play-Fairway Analysis of Washington State Prospects	Pacific and Cascades	Washington Division of Geology and Earth Resources	David Norman	$28,584	$246,367
Comprehensive Analysis of Hawaii's Geothermal Potential Through Play Fairway Integration of Geophysical, Geochemical, and Geological Data	Pacific and Cascades	University of Hawaii	Nicole Lautze	$38,432	$347,733
Structurally Controlled Geothermal Systems in the Central Cascadia Arc-BackArc Regime, Oregon	Pacific and Cascades	University of Utah	Phil Wannamaker	$52,165	$469,487
The Convergence of Heat, Groundwater, and Fracture Permeability: Innovative Play Fairway Modelling Applied to the Tularosa Basin	Rio Grande Rift	Ruby Mountain Inc	Greg Nash	$77,259	$305,036
Hydrogeologic Windows: Regional Signature Detection for Blind and Traditional Geothermal Play Fairways	Rio Grande Rift	Los Alamos National Lab	Richard Middleton	$44,444	$400,000
Geothermal Play Fairway Analysis, Snake River Plain, Idaho	Snake River Plain	Utah State University	John Shervais	$66,360	$500,000

Geographic regions were updated based on the selected research locations and expanded to five regions: Pacific and Cascades, Rio Grande Rift, Basin and Range, Snake River Plain, and Appalachian Basin.

3.1 Pacific and Cascades

3.1.1 ATLAS Geosciences, Inc.: Geothermal Potential of the Cascade and Aleutian Arcs, with Ranking of Individual Volcanic Centers for their Potential to Host Electricity-Grade Reservoirs

The US leads the world in geothermal power production, yet neither the Cascade nor Aleutian arcs currently support electricity production. However, outside the US much of the world's geothermal power comes from active arc settings. Hence, a study of the geothermal potential of the Cascade and Aleutian arcs has been undertaken.

A variety of statistical methods are being used to evaluate inter-relationships and correlations with economic geothermal reservoirs based on a number of factors, including 1) structural setting (extensional, transtensional, compressive), 2) reservoir host rock characteristics, 3) position of the volcanic center in the arc (along strike and relative to fore-arc vs. back-arc), 4) subduction rate, 4) subduction incidence angle (oblique vs. direct), 5) presence of offsets to the arc trend, 6) youthfulness and eruption frequency, 7) magma composition, 8) presence of confining caps and degree of dissection, 9) presence of thermal features (fumaroles, hot springs), and 10) fluid chemistry. The resulting statistical relationships and correlations will be used to estimate probabilities and build play fairway exploration models similar to those utilized in petroleum exploration.

Preliminary evaluation of volcanic centers world-wide has been initiated to evaluate Cascade and Aleutian arc volcanic centers for their geothermal development potential in the context of what is known at producing (and non-producing) systems world-wide in arc settings. A number of play fairway types and component hierarchal tiers have been identified. These are considered preliminary because it is believed that the continued process of data gathering, evaluation and exploration will provide quantitative information with which to refine these classifications. Potential play fairway types under consideration include:

1) Liquid-dominated systems
2) Vapor-dominated systems (where confinement plays a more crucial role)
3) Intermediate to felsic-volcanism-dominated systems
4) Basaltic-dominated systems (potentially requiring more frequent volcanism)
5) Various permeability setting plays, including, for example:
    a) strike-slip pull-apart structures
    b) extensional grabens
    c) other structural settings, including volcanic breccias, dome margins, or,
    d) primary permeabilities in carbonates, sandstones, or breccias.

Models of these primary fairway types along with additional unique characteristics are being compiled to develop a set of fairway types found in the Aleutian and Cascade arcs. These fairway types will be compared to similar fairway models globally in arc settings in later phases of this work. A more finalized list of play fairway types and component hierarchal tiers will be developed as the data are explored and the research progresses.

3.1.2 Washington Division of Geology and Earth Resources: Geothermal Play-Fairway Analysis of Washington State Prospects

Unlocking the geothermal resource of the Pacific Northwest requires innovative methodologies that address complex patterns of crustal deformation, dense vegetation, glacial veneers, extreme precipitation that erodes heat at very shallow depths, and surficial alteration. The play-type with the highest geothermal favorability in Washington State is found adjacent to active faults near the central axis of the magmatic arc. Natural permeability along faults and associated fractures can provide vertical pathways capable of tapping deep heat sources related to magmatism and can access large fracture networks that could serve as geothermal reservoirs.

The Washington Division of Geology and Earth Resources (WADGER) will enhance the Geothermal Favorability Model of Washington State that has already been partly developed by: 1) adding existing data not already incorporated into the state-wide model, 2) resampling the data already collected at a higher spatial resolution, 3) modelling simulations and data processing routines to incorporate additional variable weighting and a modified radius of influence scheme within the existing statewide scheme, and 4) using two new techniques to model fault permeability. Work will focus on three areas: the Wind River valley near Carson, WA; the Mount St. Helens seismic zone north of the volcanic monument; and the southeast flank of Mount Baker. All three of these plays have current geothermal lease holders with plans for exploration and are developable if sufficient resources are found.

Fault permeability analysis will be used to produce maps of GPS-derived velocities and strain rates, cross sections of model-derived Coulomb stress, an assessment of the uncertainty in the model predictions, and an assessment of reservoir potential. Maps and cross sections of fault slip tendency and displacement will also be produced to indicate the potential for the faults themselves to act as fluid conduits or barriers that compartmentalize the reservoir. A geothermal resource potential model will be formulated by integrating the reservoir potential with the heat model. Finally, WADGER will make recommendations for the most cost-effective exploration activities to test and/or better constrain the fault models for each play.

3.1.3 Energy & Geoscience Institute of the University of Utah: Structurally Controlled Geothermal Systems on the Central Cascadia Arc-BackArc Regime, Oregon

EGI and partners will conduct a play fairway analysis for geothermal resources in the central Cascades Range of Oregon. This area is a regime where Basin and Range style extension is being superimposed upon active arc magmatism creating multiple mechanisms for producing geothermal resources.

For central Cascadia, an inventory of resource plays will be defined using a combination of magneto-telluric (MT) data, structural geology, heat flow and fluid geochemistry based on existing data sources to estimate localized areas with a high probability of play elements. As a geophysical method, MT has recently been recognized as having particularly high potential for imaging deep magmatically-related heat sources, as well as large-scale permeability zones carrying fluids connecting the heat sources to exploitable reservoirs. Structural geology analysis seeks favorable settings for dilatency (permeability and space creation) corresponding to the geophysical structures that would allow advection of heat and fluids toward the surface.

This project will exploit the extensive coverage of the region by Light Detection And Ranging (LIDAR) data which has the ability to image fine scale, distributed structure through forest canopy. High heat flow is characteristic of this fairway, well constrained by many drillhole measurements, and should bear correlation with positive geophysical anomalies and structure. Fluid geochemistry, in particular isotopes, is a further reliable indicator of deep, high-temperature heat sources and fluid movement; spring and well fluid analyses will be correlated with implications of high-temperature fluid flow from the companion methods. Coupled parameter geochemical modeling will also estimate temperature at depth where drilling is absent as well as mineral assemblages for comparison to resistivity structure. Play fairway risk will be assessed using a simple Common Risk Segment analysis that emphasizes the downweighting of a potential prospect if any play element is deemed of high risk.

3.1.4 University of Hawaii: Comprehensive Analysis of Hawaii's Geothermal Potential Through Play Fairway Integration of Geophysical, Geochemical, and Geological Data

The state of Hawaii's unique geologic setting makes it an exceptional candidate for geothermal resource development. As a remote island state, Hawaii is more dependent on imported fossil fuel than any other state in the U.S., relying on oil for approximately 90% of the state's energy. The only known geothermal resource in Puna (on Hawaii Island's active Kilauea volcano) is a region of exceptionally high geologic risk. This project offers the opportunity to study and analyze other regions where probable resources exist but lack adequate assessment.

The University of Hawaii and partners will develop an exploration strategy for blind geothermal resources in Hawaii centered on Play Fairway Analysis of geologic, geophysical, and geochemical datasets. Data will be integrated into maps that show the probability of encountering a subsurface resource statewide. Data integration methods include: 1) identification, classification and ranking of available datasets; 2) building vector and raster data layers in GIS for geostatistical analyses; and 3) the application of statistical methods to appropriately weight key resource properties based on each dataset using a matrix of area-specific conditions and constraints. The intended products of this effort will consist of a state-wide map showing areas both that lack data (data-gaps) and that are key resource prospects; direction on the next steps to validate one or more resource(s); and a formal methodology for geothermal prospecting that can be adapted to other regions and other types of resources.

The University of Hawaii and partners will be the first to apply geothermal Play Fairway Analysis in this tectonic regime, therein enabling the categorization of blind geothermal systems more universally. Given that the 1983 assessment of geothermal resources had promising findings statewide, and that little geothermal exploration has been done in the past three decades, there is a clear need to reassess geothermal resources in Hawaii, and provide a new successful methodology to stakeholders that can reduce the risk in exploration and development.

3.1.5 University of California, Davis: Geothermal Play Fairway Analysis of Potential Geothermal Resources in NE California, NW Nevada, and Southern Oregon: A Transition Between Extension-Hosted and Volcanically-Hosted Geothermal Fields.

Two teams of scientists from the University of California at Davis (UCD) and the Lawrence Berkeley National Laboratories (LBNL) will focus on a rural region of northeastern California (Modoc and Lassen Counties), northwestern Nevada, and southern Oregon. The region is the site of two geological environments that can increase temperatures at shallow depths within the Earth. To the west is a volcanically active area known as the Modoc Plateau. Already some communities in the region use geothermal waters for space and industrial heating. To the east is a broad region known as the Basin and Range that extends from eastern California to Utah. In the Basin and Range, the Earth is stretching, allowing hotter rocks from deeper in the Earth's crust to rise closer to the surface. Several geothermal power plants in Nevada and California exploit this shallow source of heat. However, the area to be studied by the UCD/LBNL team has only seen limited use of geothermal energy thus far.

The project will involve three main tasks: 1) Gathering existing data sets and possibly reprocessing those data using newer techniques available at the two institutions; 2) Placing the combined data into software platforms that allow enhanced analysis. These will include visualization exploiting the geographic information systems (GIS) available at the Lawrence Berkeley National Laboratory, and the use of the KeckCAVE immersive 3-D visualization environment at the Department of Earth and Planetary Sciences at UCD; and 3) Developing the risk analysis procedures and software that will allow the teams to assess the potential for the development of geothermal resources in the region.

3.2 Rio Grande Rift

3.2.1 Los Alamos National Lab: Hydrogeologic Windows: Regional Signature Detection for Blind and Traditional Geothermal Play Fairways

The goal of this project is to develop a methodology to identify blind geothermal systems associated with "hydrologic windows" across the Rio Grande Rift and southern Basin and Range Provinces using a multi-fidelity signature detection framework that will allow stakeholders to interpret a wide range of geologic, geophysical, geochemical, and hydrologic data. Hydrologic windows are associated with regional, topographically-driven groundwater flow systems with circulations depths of up to 6-8 km. They are associated with areas of groundwater discharge through breached regional aquitards in lowland environments. Examples of these systems in New Mexico include the Rincon (T > 100°C), Radium Springs (T > 60°C), Truth or Consequences (T > 40°C) and Socorro (T > 40°C) geothermal systems. Presently, no formal approach exists that can identify hydrologic windows in blind geothermal systems. They are typically discovered serendipitously during well drilling.

Six signatures have been identified that can be used to identify these systems including: 1) sub-crop mapping of areas where regional confining units have been removed by erosion, faulting, or dike emplacement; 2) geomorphic analysis to identify lowland areas where discharge zones may exist; 3) trace element geochemical exploration will be used in conjunction with hydrologic path line analysis to "back track" these lithium and boron tracers up gradient to potential hydrologic windows; 4) crustal heat flow modeling to determine if a prospect has the potential for high temperature fluids at depth; 5) fault analysis to assess the likelihood that large displacement faults may create a hydrologic window; and 6) remote sensing will be used to help identify and characterize recharge areas and, where present, identify potential discharge areas. Based on this GIS analysis LANL will select two of the most prospective sites and develop cross-sectional hydrothermal models that will include representation of trace-element geochemical transport. These models will be calibrated using available thermal and hydrologic data. It is anticipated that this proof-of-concept framework could have a transformational impact on geothermal exploration in New Mexico and Arizona.

3.2.2 Ruby Mountain Inc.: The Convergence of Heat, Groundwater, and Fracture Permeability: Innovative Play Fairway Modelling Applied to the Tularosa Basin

The Energy & Geoscience Institute at the University of Utah (EGI) has teamed with Ruby Mountain, Inc. (RMI) to identify areas with high potential for both low and moderate temperature geothermal resources, located in the Tularosa Basin in New Mexico and Texas. This will be accomplished using existing data representing 1) heat of the Earth; 2) the presence of subsurface fluids for heat transfer; and 3) the presence of structural geometries that produce critical stress and resultant fracture permeability.

Two PFA models are anticipated for this project, one based upon weights-of-evidence statistics and another which will be closely related to the traditional knowledge-based PFA as used by the petroleum industry. A concerted effort has been underway since the project's inception to collect related data and develop a GIS database to support PFA, and this growing dataset is lending early encouragement that PFA will be a viable technique to apply to the study area. The Tularosa Basin is home to several military installations with aggressive renewable energy goals which would benefit if new geothermal resources were to be discovered.

3.3 Basin and Range

3.3.1 Nevada Bureau of Mines and Geology: Discovering Blind Geothermal Systems in the Great Basin Region: An Integrated Geologic and Geophysical Approach for Establishing Geothermal Play Fairways

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), but sedimentary-hosted and EGS systems will also be assessed. Successful exploration and development of these systems relies on accurately defining permeable zones in 3D space.

At this time, no single tool can define the detailed structural framework of a geothermal area and fault segments that host fluids. Therefore, the team is employing a multi-disciplinary approach that combines conventional and innovative techniques into a concerted effort aimed at characterizing the signatures of geothermal systems and providing detailed geothermal potential maps that can guide future exploration efforts. Conventional techniques employed in this study will include interpretation of geologic, geochemical, and geophysical data, as well as innovative methods involving slip and dilation tendency analysis of faults, 3D modeling, and quantitative geostatistical analysis that integrates multiple predictive parameters into geothermal potential maps.

Expected outcomes include detailed geothermal potential maps that define geothermal play fairways and identify potential blind geothermal systems in three critical areas across the Great Basin. The map and accompanying 3D models should reduce risks in the exploration and development of blind systems.

3.3.2 Energy & Geoscience Institute at the University of Utah: Structurally Controlled Geothermal Systems in the Eastern Great Basin Extensional Regime, Utah

EGI and partners will conduct a play fairway analysis for geothermal resources in the eastern Great Basin of western Utah. This area is an active extensional regime with several producing geothermal resources and the potential for numerous additions.

Resource plays will be defined using a combination of MT data, seismicity swarm analysis, heat flow, structural geology and fluid geochemistry based on existing data sources to estimate localized areas with a high probability of play elements. New techniques of seismic swarm analysis will complement the MT data, as swarms are currently regarded as reflecting the movement of magmas or subsurface fluids. Incorporating non-swarm seismic clusters may delineate blind fault zones or reflect fluid-induced failure. Structural geology analysis seeks favorable settings for dilatency (permeability and space creation) corresponding to the geophysical structures that would allow advection of heat and fluids toward the surface.

The team's intentions are to show heat flow correlation with positive geophysical anomalies and structure. Fluid geochemistry, in particular isotopes, is a further reliable indicator of deep, high-temperature heat sources and fluid movement; spring and well fluid analyses will be correlated with implications of high-temperature fluid flow from the companion methods. Play fairway risk will be assessed using a simple Common Risk Segment analysis in conjunction with GeoFRAT heat-in-place modeling that emphasizes the down-weighting of a potential prospect if any play element is deemed of high risk.

3.4 Snake River Plain

3.4.1 Utah State University: Geothermal Play Fairway Analysis, Snake River Plain, Idaho

The Snake River Plain (SRP) Play Fairway project will adapt Play Fairway Analysis to geothermal systems in southern Idaho, an area of known high heat flow. The lead institution is Utah State University (Logan, UT); additional partners include the Center for Geophysical Investigation of the Shallow Subsurface (Boise State University, ID), the U.S. Geological Survey (Menlo Park, CA), Lawrence Berkeley National Laboratory (Berkeley, CA), the National Renewable Energy Laboratory (Golden, CO), Leidos Inc. (San Diego, CA), and Geoscience Technology & Engineering (Salt Lake City, UT).

Although the Snake River Plain is part of the highest heat flow anomaly in the US, it has experienced very little geothermal exploration. The project team believes that this results from the lack of obvious high temperature manifestations (except for Yellowstone) and the dominantly basaltic nature of the province. In this project they will address systems that are related to basalt magmatism and basalt differentiates, as well as the young rhyolite domes. Three different play types have been identified in the SRP: 1) high thermal gradients along the volcanic axis beneath the SRP aquifer, 2) extremely large low temperature systems, and 3) blind high-temperature systems like that discovered at Mountain Home.

The goals of this project are: 1) to adapt the methodology of Play Fairway Analysis for geothermal exploration, creating a formal basis for its application to geothermal systems, 2) to assemble relevant data for the SRP volcanic province from publicly available and private sources, and 3) to build a geothermal play fairway model for the SRP that will allow us to identify the most promising plays, using software tools that are standard in the petroleum industry. If chosen to move forward to Phase 2, the plays identified during Phase 1 will be used to locate specific prospects that the models suggest offer the greatest potential for success. A particular emphasis will be placed on blind resources that may be overlooked using traditional approaches to geothermal exploration.

In terms of geothermal energy development, the SRP is one of the highest heat flow regions in the United States. Idaho was ranked 3rd among western states for potential geothermal power production by the Geothermal Task Force of Western Governors Association, which estimated that Idaho has 855 MW of near-term economic potential resources. Much of this potential lacks obvious surface expressions, making a systematic fairway analysis critical to its development. The SRP Fairway team will leverage its expertise in both geothermal systems and petroleum exploration to effectively adapt oil and gas fairway analysis to geothermal exploration.

3.5 Appalachian Basin

3.5.1 Cornell University: Low-Temperature Geothermal Play Fairway Analysis for the Appalachian Basin

A team of geologists, geophysicists and engineers from Cornell University, Southern Methodist University, and West Virginia University are analyzing the collective risk associated with factors whose co-occurrence, or avoidance, would reduce the costs of developing geothermal energy in the Appalachian Basin. The footprint of the project covers most of West Virginia and all of central and western New York State and Pennsylvania. Broad regions of the basin in all three states have heat fluxes in excess of 50 mW/m^2.

Where available, the team will apply gravity, magnetics, faults, seismicity and other geological formation information from a range of sources to map the spatial and depth distributions, thereby defining individual risk factors for geothermal play fairways for the Basin. The products of this study will be quantified maps of the collective risks associated with three factors in addition to the thermal resource itself. In principle, low risk projects will be selected for the co-location of shallow heat resources, natural reservoir rocks, and communities, and the avoidance of faults. The project utilizes thermal data from tens of thousands of oil and gas wells from state geological surveys data for the spatial distribution of pore volumes, and numerical models that have been developed and tested which estimate the costs of direct-use applications as functions of resources, flow rates, and project designs.

4. NEXT STEPS

4.1 Peer Review

The next GTO Peer Review will be held the week of May 11, 2015 near Denver, Colorado. Representatives from all eleven project teams will present interim results, and participate in discussion about final reports and the downselect process. The Peer Review is open to the public and free of charge.

4.2 Downselect

The competitive downselect process will commence in September of 2015. The eleven teams will present their findings with detailed recommendations for further exploration in their areas of study to a panel of independent reviewers. Each project will be scored on the criteria below. Approximately 3-5 projects are expected to move on to Phase 2. The criteria, as listed in the FOA, are as follows:

1. The technical strength of the methodology employed in the analysis
2. Utility of the methods for potential application at other sites
3. The degree to which the Phase 1 report presents a rigorous quantification of project risk
4. Commercial viability of the play

These criteria are intended to identify those projects with the most transferable methodology, as well as the most promising areas of study. Due to budget limitations, not all projects that meet Phase 1 objectives will have the opportunity to continue to Phase 2.

4.3 Phase 2

Phase 1 final reports will contain a wide range of recommendations, from continuation of desktop analysis to drilling of temperature gradient wells or slimholes. DOE is exploring a range of options to support Phase 2 drilling if a viable plan is approved. In the event that one or more project teams are ready for exploratory drilling in Phase 2, DOE is investigating the possibility of contracting a drilling rig directly to perform the work. A USGS rig could be used under an interagency agreement, or a private company could be contracted. This would be a departure from past projects, where for-profit recipients often had the capability to manage drilling and DOE involvement was more limited to usual grant oversight functions.

Land access and permitting may be significant obstacles to drilling. Project teams are advised to consider these issues in preparing their recommendations. Much of the area under study is public land, so discussions have been initiated between DOE and the Bureau of Land Management (BLM) to find the most efficient route for permitting.

4.4 Play Fairway Funding Opportunity for late 2015 / early 2016

The 11 current play fairway project teams include a mix of small private companies, research universities, and DOE national laboratories. Interestingly, none of the large geothermal developers submitted an application for this opportunity. It is DOE's intent, dependent on Congressional language and availability of funds, to craft another play fairway FOA in 2015 that will be intended to attract industry participation. A formal request for information (RFI) is planned for spring 2015 to solicit input from industry on this initiative, and additional information will be available by the middle of this year.

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