Geothermal Prospector: Supporting Geothermal Analysis Through Spatial Data Visualization and Querying Tools

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ABSTRACT

Determining opportunities for geothermal energy can involve a significant investment in data collection and analysis. Analysts within a variety of industry and research domains collect and use these data; however, determining the existence and availability of data needed for a specific analysis activity can be challenging and represents one of the initial barriers to geothermal development [2]. This paper describes the motivating factors involved in designing and building the Geothermal Prospector application, how it can be used to reduce risks and costs related to geothermal exploration, and where it fits within the larger collection of tools that is the National Geothermal Data System (NGDS) [5].

Introduction

There is an inherent cost in locating the data and performing the initial analysis needed in identifying opportunities for geothermal technologies. More than other renewable energy technologies, the data needs for geothermal exploration are varied and distributed across numerous institutions, companies, and state agencies. Moreover, the data required to identify a geothermal resource is complex, often requiring interpretation and aggregation of multiple data sets. This is, and has been, seen as a major obstacle in geothermal development [2]. The U.S. Department of Energy's Geothermal

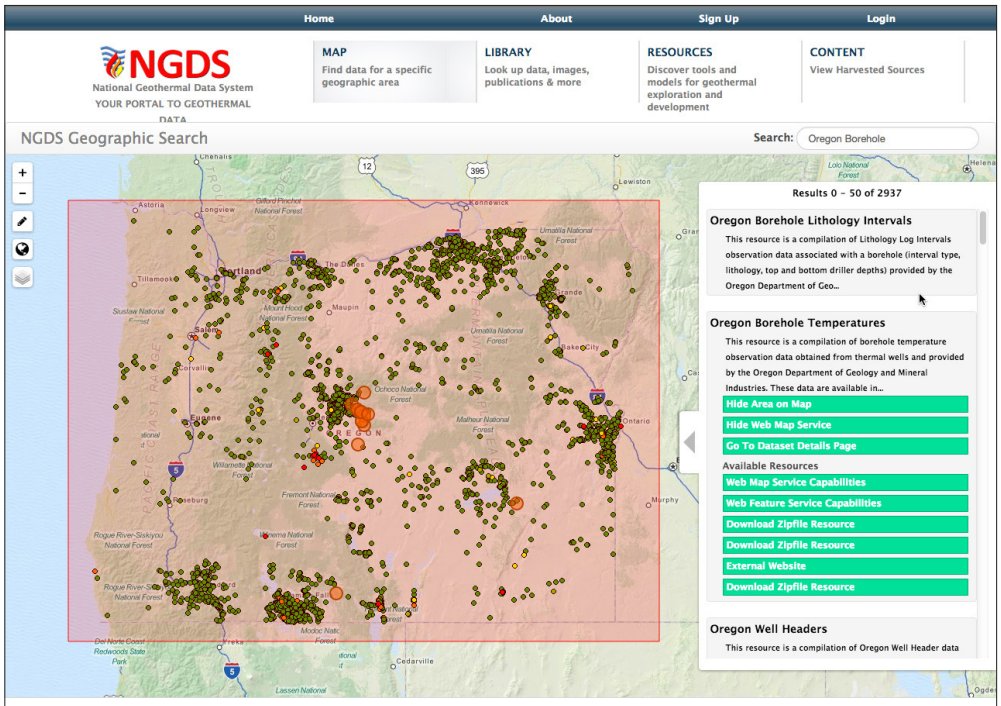

Figure 1. Accessing borehole data for Oregon in the NGDS. (http://www.geothermaldata.org/ngds/map?query=oregon+boreholes)

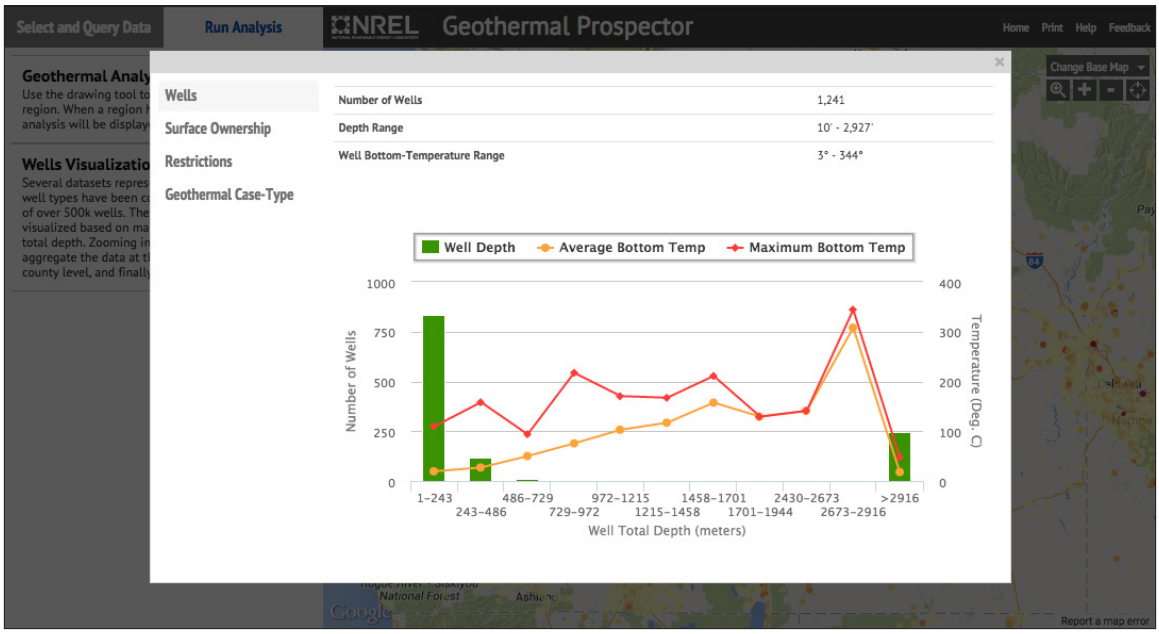

Figure 2. Visualizing a summary of temperatures at depth for boreholes in Oregon.

Technologies Office (DOE GTO) recognizes this need and has developed a plan, secured funds, and is supporting the development of technologies and procedures to facilitate the gathering of the metadata, and in some cases the actual data, so that stakeholders know what data is available and where it can be accessed for analysis. These efforts are intended to encourage investment through reducing the risk of these initial analysis activities, a need expressed by Deloitte LLP in their 2008 report [3] and described in the 2011 DOE strategic plan [7]. Efforts such as the National Geothermal Data System (NGDS) [5], the Geothermal Data Repository (DOE-GDR) [4], and the Geothermal Prospector are part of a coordinated strategy to fill this need in the geothermal community.

Although the National Geothermal Data System user interface provided at geothermaldata.org provides access to data sources and highly structured data, the geothermal prospector can be used to visualize and query specific data from NGDS in conjunction with other data and analysis capabilities available in that application.

For example, the NGDS user interface shows the location of specific boreholes (figure 1).

The Geothermal Prospector can provide access to summary analyses and a complex filtering capability of these same data (figure 2).

The intent of the Geothermal Prospector is to provide access to explore, query, visualize, and download data necessary for understanding the costs, risks, and potential for geothermal renewable energy. Additionally, the Geothermal Prospector provides a venue for spatial datasets resulting from DOE funded research to be shared with the public, research communities, and industry.

Project Background and Intent

In 2011, the National Renewable Energy Laboratory (NREL) developed the first version of the Geothermal Prospector application. Geothermal Prospector is, at its core, a web-based GIS application designed to support the exploration, visualization, and querying of data related to geothermal exploration.

This application utilizes the OpenCarto framework and the architecture behind developer.nrel.gov. OpenCarto is a web based GIS framework, which currently supports independent applications in solar, wind, hydrogen, marine hydrokinetic, transportation, biomass, biofuels, and geothermal. Through the utilization of these frameworks, each application shares data, resources, and analysis capabilities. This reduces both the short-term development costs as well as the long-term maintenance costs. This framework, and in turn the Geothermal Prospector, has only recently finished going through a significant update to provide a more intuitive and performant interface and to facilitate more sustainable data management practices. Developer.nrel.gov (http://developer.nrel.gov) is NREL's flagship web services platform and forms the basis for the web services provided at API.data.gov. All of the analysis capabilities in the Geothermal Prospector are made possible by web services available through Developer.nrel.gov.

Geothermal Prospector provides a tool for geothermal stakeholders to explore, visualize, and download the best data and analysis that can be freely provided by the local, state, Federal government and others who want to provide open

data. By providing the data needed for exploration and opportunity assessment, the Geothermal Prospector reduces the inherent cost/risk in running first tier analysis within the continental United States.

This project represents a needed component in the suite of DOE GTO provided tools. Data from the GDR that is of a spatial nature can be served to the NGDS, and others platforms, through the Geothermal Prospector. In turn, data in the NGDS can be accessed, visualized, queried, and downloaded through the Geothermal Prospector. The standards-based data services that Geothermal Prospector uses to communicate with the NGDS also allow it communicate with other software and applications using the same standards.

Designing the Geothermal Prospector to Support Geothermal Analysis

The Geothermal Prospector has three fundamental functions developed specifically to support the geothermal research community. These include the provision of access to visualize, query, and explore combinations of data needed in first cut analysis of site selection, the provision of preconfigured analysis capabilities focused on using these data to identify locations with good potential for geothermal technologies, and the provision of a visualization capability for large or complex datasets.

In all of these capabilities, the geothermal prospector is attempting to fill gaps in the tools and capabilities available in the geothermal research community. Some examples of these use cases include:

- Users who do not have access to or experience using GIS software but are interested in
  - Doing a first tier analysis of geothermal resource/data
  - Visualizing data from NGDS
  - Sharing data or collaborating with others interested in the same area
  - Gathering all data on an area of interest in one spot to explore or verify an opportunity
- Users who want to identify areas with some geothermal quality of interest
  - Proximity to existing plant or identified site
  - Proximity to wells with high temperature (AASG data)
  - Proximity to existing leases or exploration
  - Look for areas that are “data rich” – lots of wells in area to support resource
- Users who want to get a general idea of the geothermal resource in their area, and/or want to develop preliminary maps of the geothermal resource in their area
- Users who want to identify features mentioned in papers and verify locations where the literature indicates a geothermal resource

Data Access and Visualization

The Geothermal Prospector provides access to over eighty datasets including environmental restrictions, known geothermal resource areas, geologic maps, infrastructure including wells and currently developed sites, land ownership, political boundaries, and topology to name a few categories of data. These data represent the most current data available that can be provided to researchers and industry by the federal government. Additionally, the use of standards-based services allows for the dynamic inclusion of supplemental datasets. Through the application interface, users can:

- Basic Features
  - View metadata about a dataset (figure 3)
  - Explore data spatially (zooming and panning)
  - Load several data layers simultaneously to view overlapping areas
  - Alter the ordering and transparency of data layers
  - Download data as CSV, SHP, KML, and GeoJSON (figure 3)
  - Query data by point or region and download the results as a CSV
  - Print the view of data representing the layers, their order, and the zoom level
- Advanced Features
  - Turn on and off classes in the data to show only the data of interest on the map, referred to as Layer Threshold Setting (figure 4)

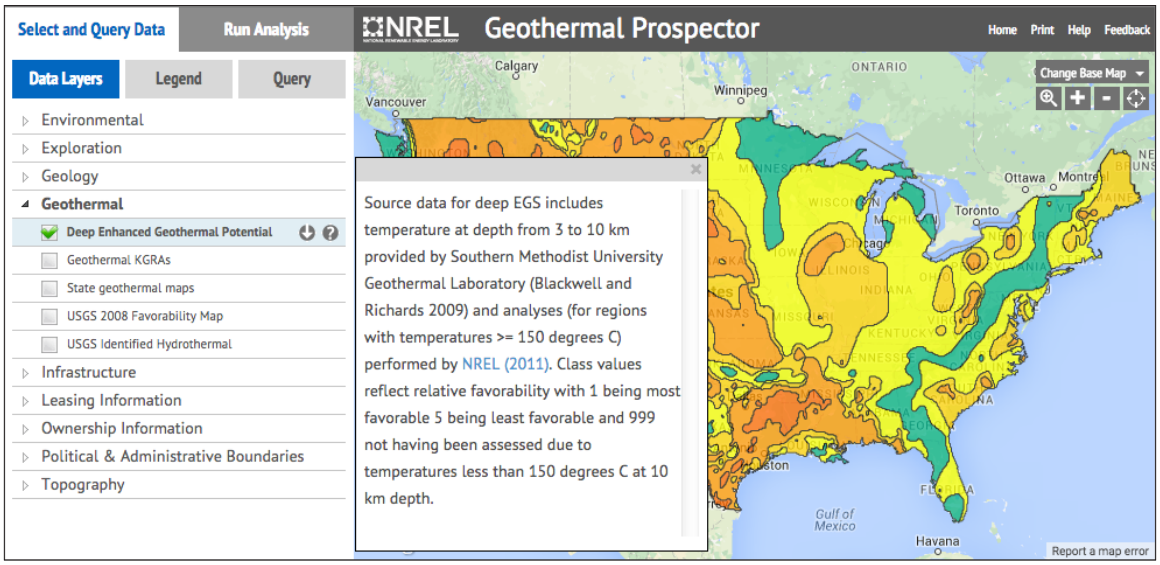

Figure 3. Metadata for data layer.

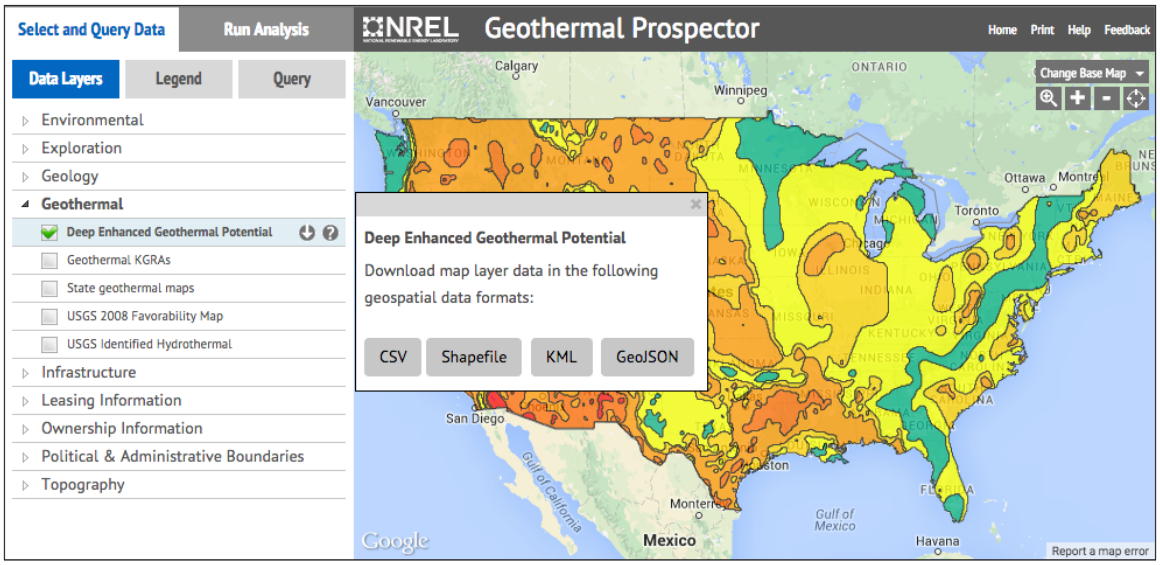

Figure 4. Data download option for data layer.

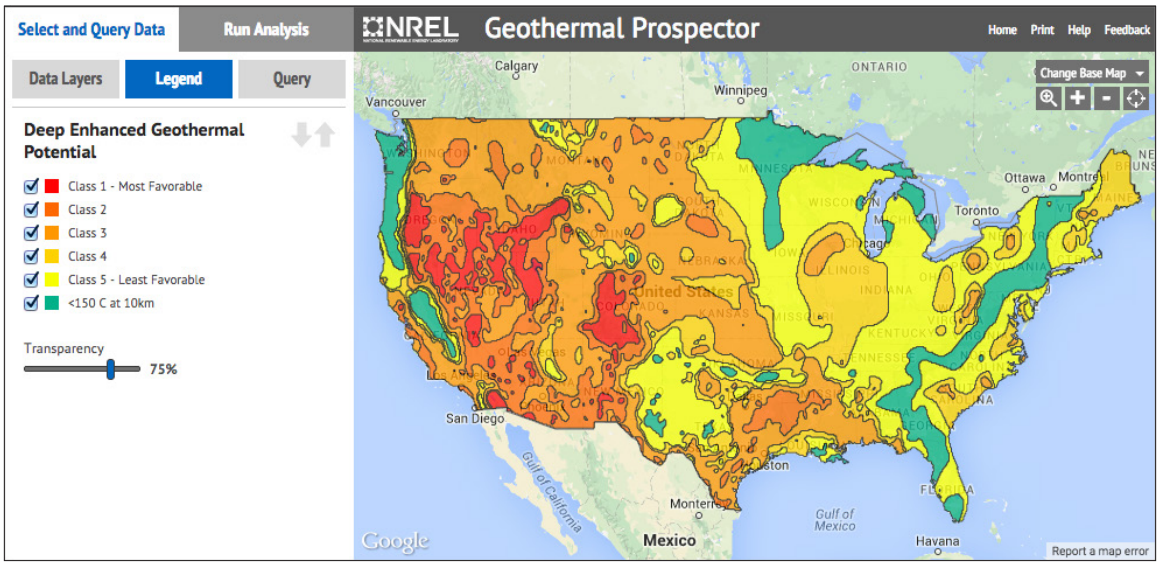

Figure 5. Layer threshold setting (all classes).

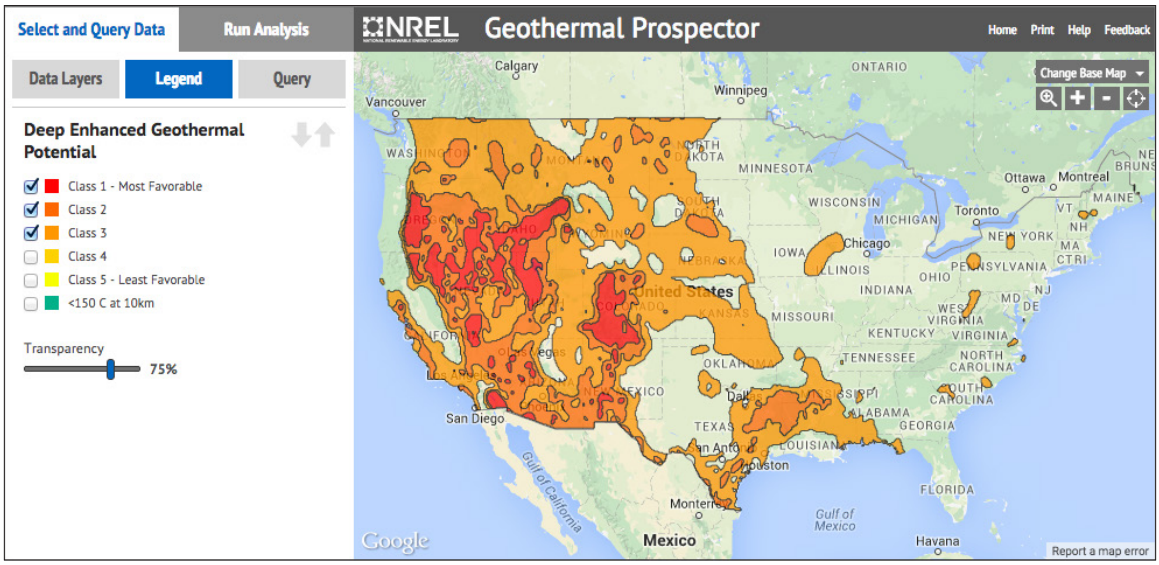

Figure 6. Layer threshold setting (subset of original classes).

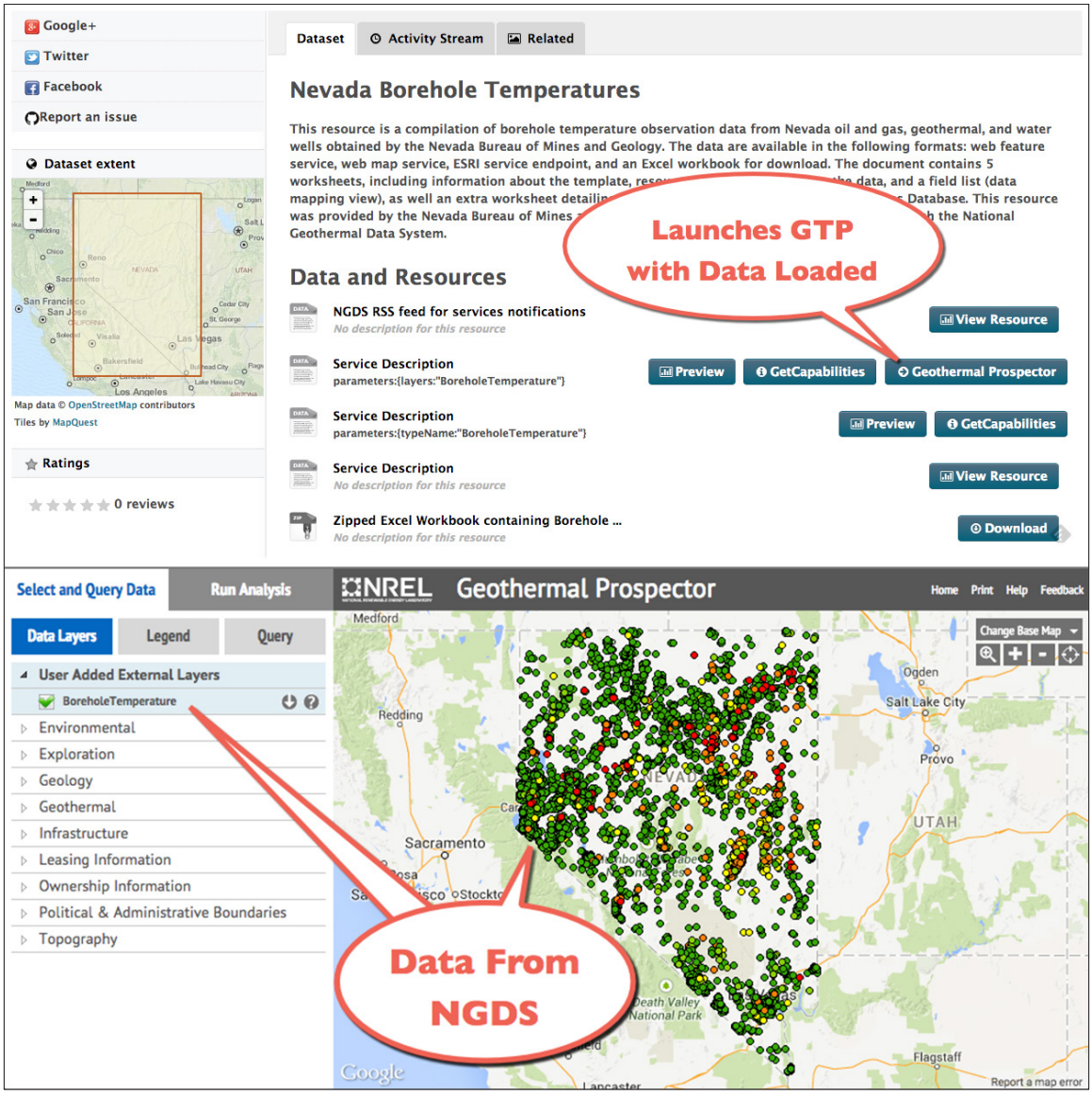

Figure 7. Interoperability between NGDS and the Geothermal Prospector.

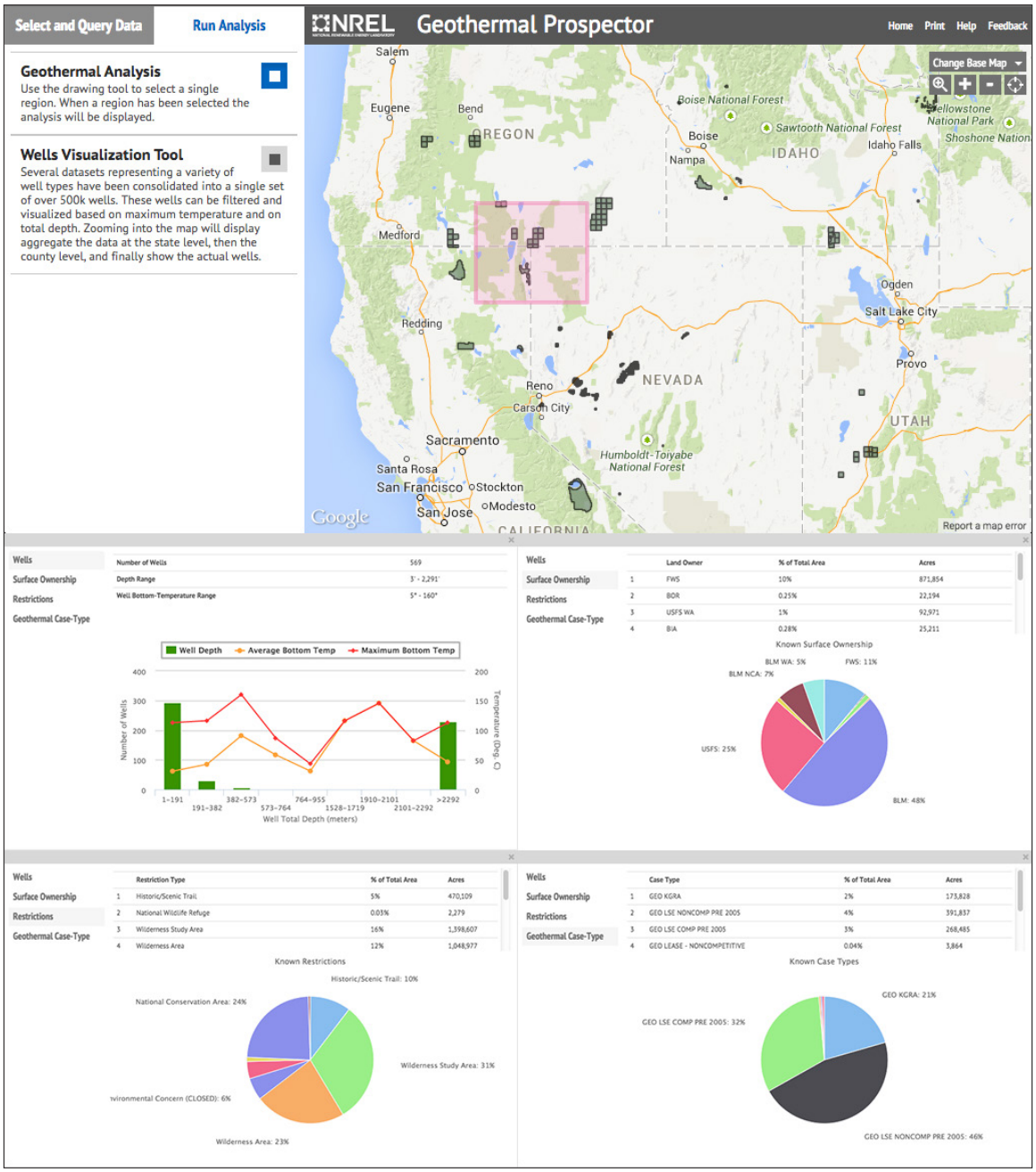

Figure 8. Summary Analysis showing distribution of wells, land ownership, land use restrictions, and current leasing information.

- Share the view of data representing the layers, their order, and the zoom level
- Perform attribute queries that allow filtering of the data per user specified values

In addition to visualizing the data within the Geothermal Prospector application, users can also load data into the application directly from the National Geothermal Data System (NGDS). Data layers within the NGDS that have Open Geospatial Consortium (OGC) standard services including Web Mapping Service (WMS) and Web Feature Service (WFS) [6] are available to load directly into the Geothermal Prospector (figure 5). Additional capabilities planned for the Geothermal Prospector included the ability to load any datasets that follow the OGC standard and also the capability to directly browse the NGDS.

Summary Analysis

Although the data needed to evaluate geothermal opportunities can very significantly depending on the technology being evaluated, several datasets represent common denominators in that process. These include temperature at depth from wells data, land use, and land use restrictions. As a search for these data within an area of interest is such a common task,

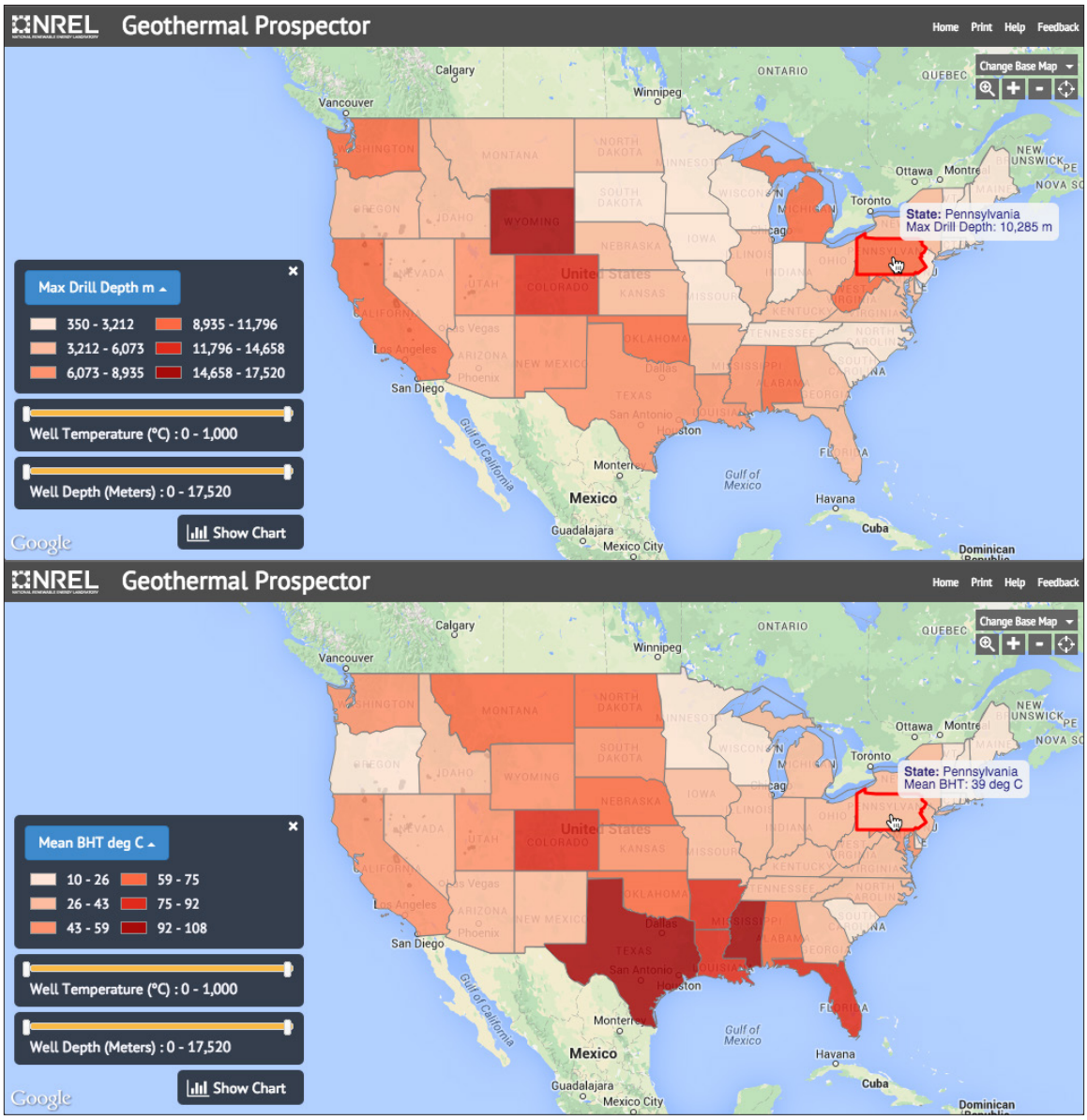

Figure 9. Distribution of well depth and max borehole temperature across the US by state.

the Geothermal Prospector has provided these both as independent layers as well as a preconfigured analysis capability. Users can drag a polygon over an area of interest and the three common datasets, as well as a dataset depicting leases related to geothermal technologies, are summarized in an interactive chart window (figure 6). This capability limits the data collection needed to perform a first tier assessment for geothermal opportunities. By lowering the costs of this process, the Geothermal Prospector provides the tools needed to focus more costly analysis on areas with a higher probability of success and effectively lowers the risk associated with exploration.

Complex Data Visualization

The data provision and exploration capabilities in the Geothermal Prospector are mainly focused on exploring single attribute datasets. Each map layer represents one aspect of a dataset, even if that dataset is comprised of many attributes. Multiple layers can be combined on a single map, which is a useful exercise in many cases, but inherently limited to the number of layers that can be actively interpreted in one view.

An effort has been made in the OpenCarto framework to develop a capability specifically focused on visualizing complex datasets. This includes data that have a large number of attributes, data that are represented as a set of scenarios, time series datasets, and very large datasets. Within the Geothermal Prospector, this capability has been applied to a subset of the AASG wells dataset [1] where data representing temperature and depth are complete (figure 7-9). In other applications, this capability enables visualizing how data change over time and between scenarios.

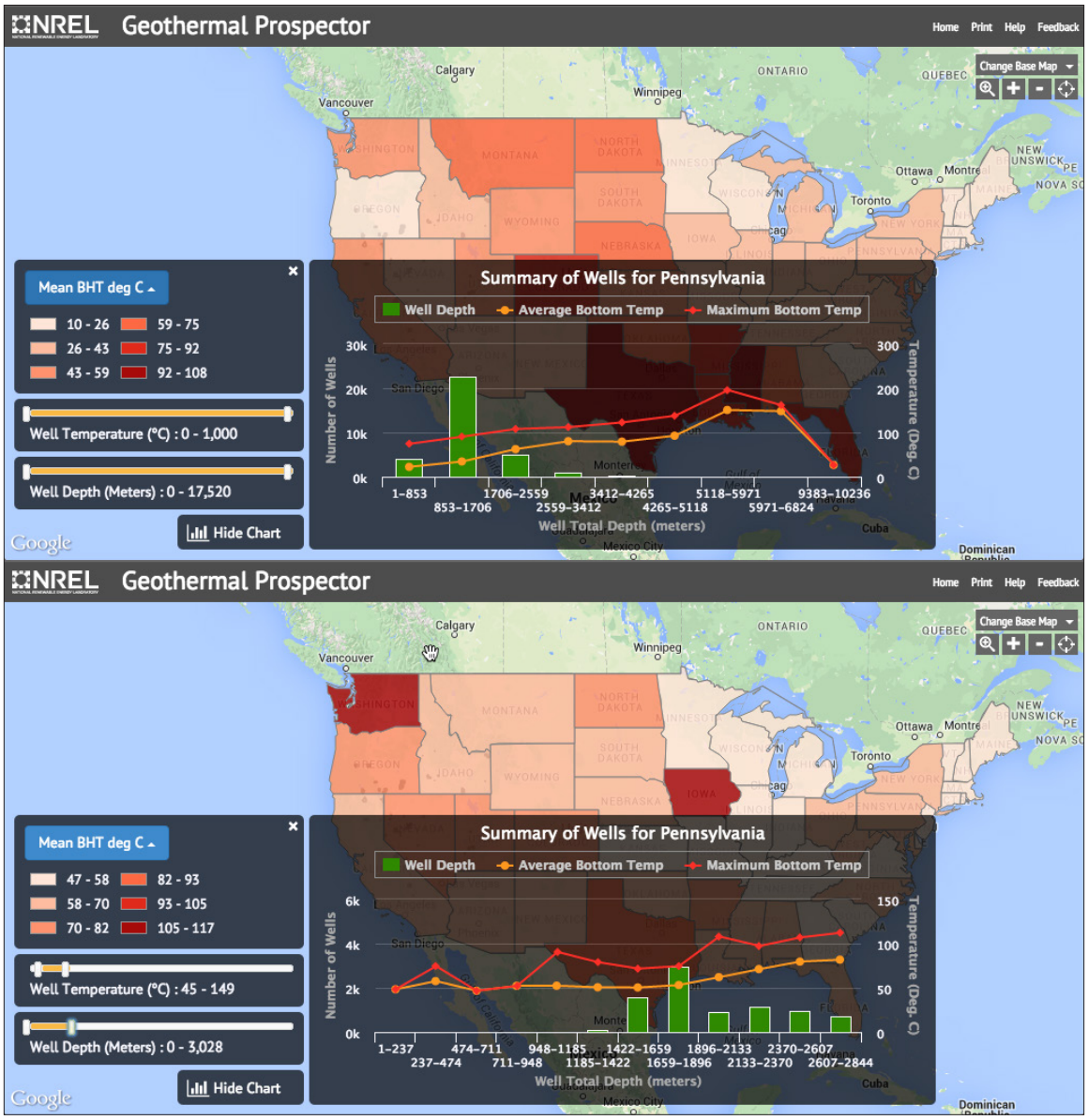

Figure 10. Distribution of max borehole temperature in PA before and after filtering based on temperature and depth.

Within the wells visualization, users can filter the data to determine where in the US data exists that would support technologies that require strict combinations of temperate and depth ranges.

Summary and Future Directions

It is clear that the DOE GTO is committed to making resource, analysis, and ancillary datasets needed for geothermal exploration and development available to stakeholders in research and industry. The National Geothermal Data System, the Geothermal Data Repository, and the Geothermal Prospector represent a coordinated effort to support this goal. As the Geothermal Prospector has reached a point of maturity in the capabilities described here, the focus is shifting to better integration with other tools, better support for data updates, and focusing additional functionality on providing direct support for DOE GTO focus areas including play fairway analysis, low temperature opportunity assessment, and systems analysis activities.

Making connections to ensure that those involved in these areas of research are aware of the Geothermal Prospector and how to utilize it both as a research tool and also as a venue to share data will be a major focus area in the current fiscal year. In this effort, the Geothermal Prospector team is facilitating outreach efforts and information sessions to demonstrate the application and provide opportunities for collaboration.

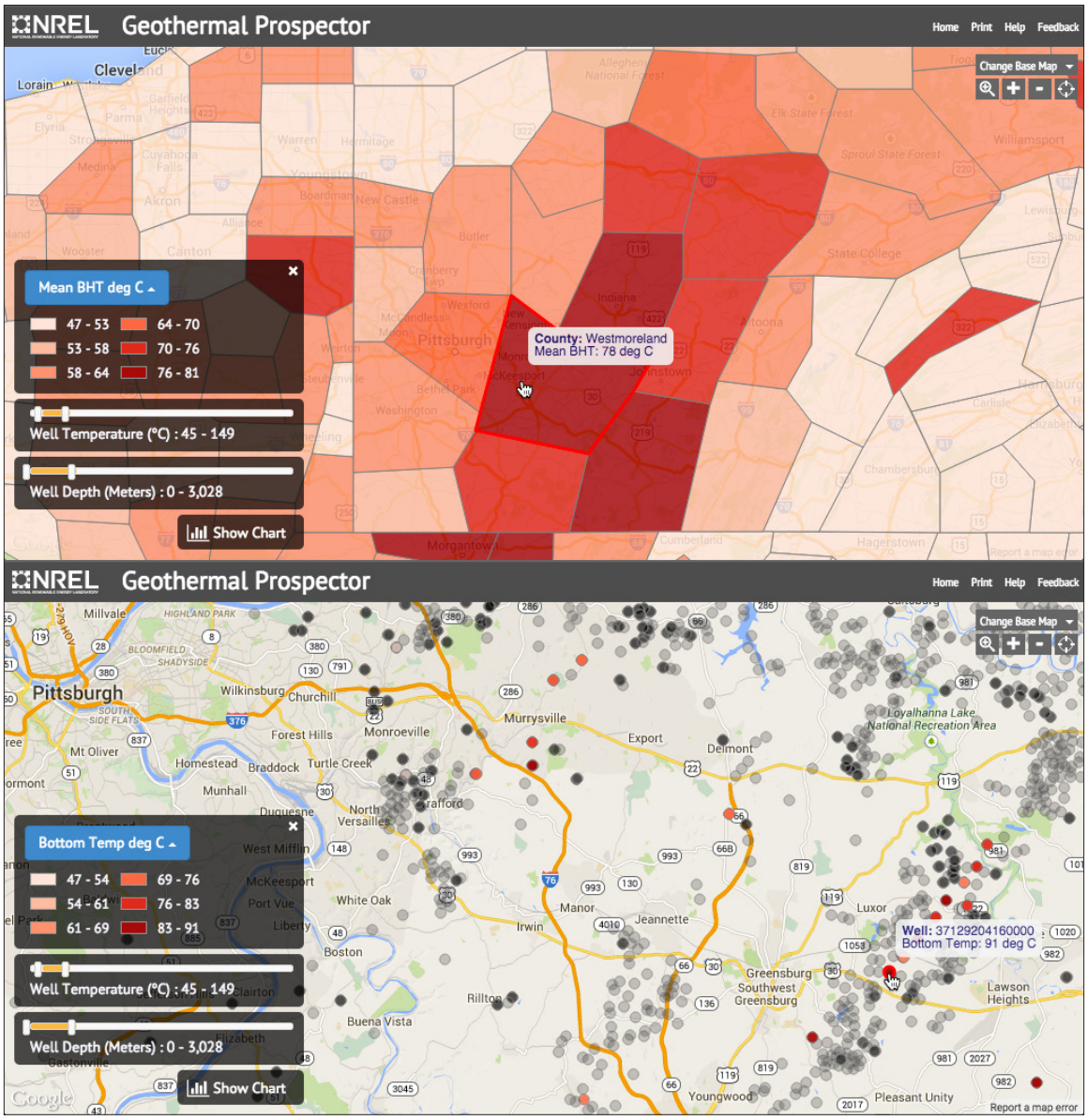

Figure 11. Distribution of max borehole temperature by county in PA and visualizing actual wells after filtering based on temperature and depth.

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