

ANALYSIS OF GAPS IN GEOTHERMAL EXPLORATION DATA IN THE WESTERN UNITED STATES

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ABSTRACT

The USGS Resource Assessment (Williams et al. 2008) outlined a mean 30 GW_e of Undiscovered Hydrothermal Resource in the western U.S. One goal of the Geothermal Technology Office (GTO) is to accelerate the development of this undiscovered resource. To help guide its future data collection efforts, GTO funded a data gap analysis in FY2012 to identify high potential hydrothermal areas where critical data are needed. For the gap analysis, information was collected about existing data and data coverage maps were created with this information. Next, these maps were compared with the USGS resource potential maps to identify priority sites for exploration data collection.

Though there are many types of data that can be used for hydrothermal exploration, five types of exploration data were targeted for this analysis. These data types were selected for their regional reconnaissance potential, and include many of the primary exploration techniques currently used by the geothermal industry. The data types include: 1) well data; 2) geologic maps; 3) fault maps; 4) geochemistry data; and 5) geophysical data. To determine data coverage, metadata for exploration data (including data type, data status, and coverage information) were collected and catalogued. Many industry, university, laboratory, and agency personnel were contacted in order to collect metadata for this effort. Data and metadata provided by the contributors to the National Geothermal Data System (NGDS) were also incorporated in the gap analysis.

An online tool was developed to allow all geothermal data providers to directly add metadata themselves and view the results of the analysis via maps of data

coverage in Geothermal Prospector
(http://maps.nrel.gov/gt_prospector).

A grid of the contiguous U.S. was created with 88,000 10-km by 10-km grid cells, and each cell was populated with the status of data availability corresponding to the five data types. Using these five data coverage maps and the USGS Resource Potential Map, sites were identified for future data collection efforts. These sites signify both that the USGS has indicated high favorability of occurrence of geothermal resources and that data gaps exist.

BACKGROUND

Because one goal of the GTO is to identify more of the nation's undiscovered hydrothermal resources, the objective of this study was to identify spatial locations with data gaps for high-level hydrothermal exploration data. While we realize that additional data needs (e.g., downhole data) are crucial in delineating and quantifying undiscovered resources, this analysis was limited in scope to regional reconnaissance data that was easily accessible and georeferenced.

Two main sources were used to guide the development of the framework for the data gap analysis: the 2011 Blue Ribbon Panel recommendations and the 2008 USGS Hydrothermal Resource Assessment. Using these two sources, the data gap analysis assesses the extent to which available data align with data needs. There were two parts of the needs analysis: identifying the types of data needed and identifying the locations where they were needed. The types of data reviewed in this analysis correspond to the types of data identified by the industry Blue Ribbon Panel as necessary for high-level assessment of hydrothermal resource potential.

The locations selected to have high potential for industry need for data were sites indicated by the USGS to have “high favorability” for hydrothermal potential.

The analysis reviewed the types of data available at each of these high-favorability locations. The gap analysis therefore reveals the locations that have high favorability for hydrothermal resources, but where insufficient data are available to fully characterize the resource. These locations with data gaps constitute the list of candidate sites for future data collection efforts to further characterize the undiscovered geothermal resource.

The gap analysis used a high-level estimate of data coverage at a 10-km by 10-km resolution. The data collection was restricted to data that were georeferenced and contained within the still-developing National Geothermal Data System (NGDS). It was considered beyond the scope of the project at this stage to do a quality and completeness assessment of the data collected. Contributors to the NGDS are currently in the process of determining standards for completeness and quality for various data types, and we did not want to duplicate those efforts.

TYPES OF DATA REQUIRED

The recommendations from the Blue Ribbon Panel (2011) convened by the GTO were used to identify the data needs of the geothermal industry. The Blue Ribbon Panel suggested locating undiscovered resources in the near term using five categories of

exploration methods: rapid reconnaissance surveys, surface exploration, stress measurements, fracture mapping, and temperature gradient drilling. The first step in the analysis was to identify data that correspond to these five areas. Five unique data types were identified, including: 1) geologic maps; 2) fault maps; 3) geochemistry data; 4) geophysical data; and 5) well data. Reconnaissance data of these types are generally collected at the regional scale.

LOCATIONS REQUIRING DATA

After identifying the types of exploration data to collect, the next step was to determine the locations where the exploration data may be needed. These locations were selected using the undiscovered resource estimate completed by the USGS in 2008 (Williams et al.). The USGS estimate of moderate and high geothermal resources focused on 13 western states: Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. It is important to note that, to estimate the undiscovered geothermal resource at a location, some amount of data must be available in proximity to that location. However, that does not imply there is complete data coverage at that site. The USGS estimated the undiscovered potential using temperature data from geothermometry and bottom-hole temperature measurements, as well as assumptions based on the key factors that are often associated with the presence of a hydrothermal reservoir, such as seismic activity and the presence of a magmatic source.

Table 1. Undiscovered hydrothermal resources (MW) at different probability levels.¹

State	F95	F50	Mean	F5
Arizona	238	775	1,043	2,751
California	3,256	9,532	11,340	25,439
Colorado	252	821	1,105	2,913
Idaho	427	1,391	1,872	4,937
Montana	176	573	771	2,033
Nevada	996	3,243	4,364	11,507
New Mexico	339	1,103	1,484	3,913
Oregon	432	1,406	1,893	4,991
Utah	334	1,088	1,464	3,860
Washington	68	223	300	790
Wyoming	40	129	174	458
Total	6,953	20,920	26,373	64,093

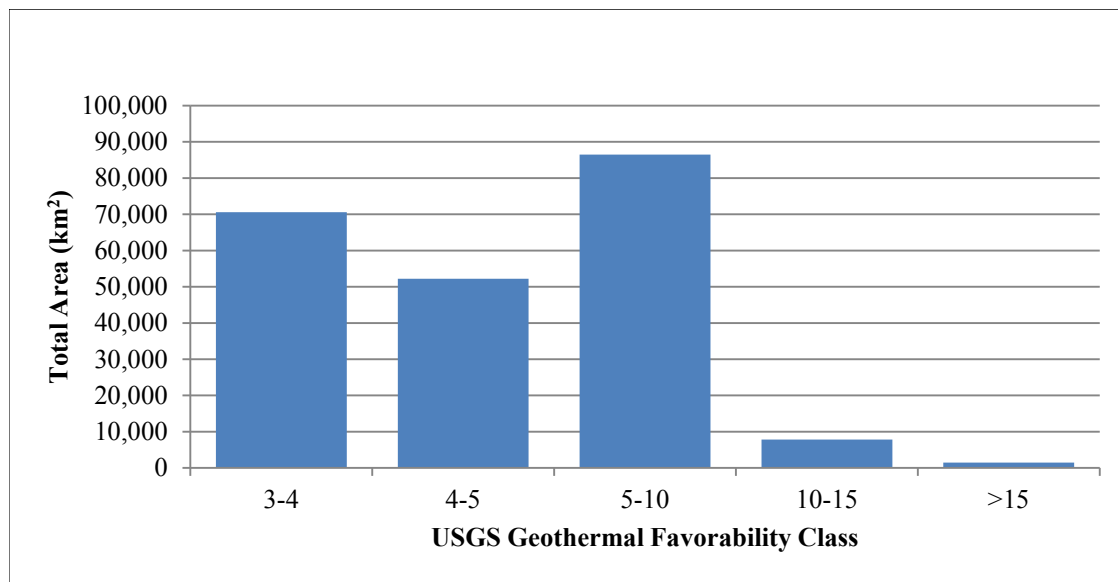


Figure 1: Total exploration demand area by power demand estimate. The exploration demand levels were taken from the USGS digital map showing geothermal favorability.

Using these data, the USGS calculated a mean of 30,033 MW_e of undiscovered geothermal resources based on an assumption of 30 years of production. In addition to this estimate, the USGS created a digital map that showed the favorability in terms of MW_e/km² for 11 of the 13 states, excluding Hawaii and Alaska. The estimated power density ranged from less than 0.1 MW_e/km² to greater than 15 MW_e/km². The mean undiscovered hydrothermal resource estimate for these 11 states was estimated to be 26,373 MW_e, and there is a 5% probability that there is as much as 64,093 MW_e of undiscovered hydrothermal resource, as shown in Table 1.

In this analysis, the first step in selecting priority locations for data collection was to remove from the USGS power density map the area where collecting exploration data is discouraged due to regulatory, policy, or feasibility issues. The area removed included federal exclusion areas, such as national parks and wilderness areas, areas designated by the Bureau of Land Management (BLM) or the Forest Service (FS) as closed to geothermal development,¹ areas where current active or pending leases exist,² urban areas with a buffer of 10 km,³ and regions with slopes greater than 30%.⁴

¹ "GIS Data." (2012). Bureau of Land Management (BLM), http://www.blm.gov/wo/st/en/prog/energy/geothermal/geothermal_nationwide/Documents/GIS_Data.html

² "GIS Data." (2012). BLM, http://www.blm.gov/wo/st/en/prog/energy/geothermal/geothermal_nationwide/Documents/GIS_Data.html

³ Free base data included with ArcGIS software purchase.

⁴ Calculated from elevation data obtained from the National Atlas (www.nationalatlas.gov).

Because the goal of this effort is to identify sites for funding of future data collection efforts, areas within 10 km of operating and developing geothermal power plants were excluded to attempt to avoid current development efforts. Currently operating plants were identified using SNL Financial's listing; SNL is a subscription-based business intelligence service that actively collects data from press releases and industry for multiple areas, including the energy sector. Their list included 67 plants in Alaska, California, Hawaii, Idaho, Nevada, Oregon, Utah, and Wyoming, with installed capacities ranging from 0.3 MW_e to 1,273 MW_e.

Estimates of the power potential of new geothermal developments were compiled from the Geothermal Energy Association annual report (2012), developed from industry surveys, and taken from SNL Financial, generated through independent research; 178 projects under development were identified. The status of these projects ranged from unconfirmed to currently under construction. Finally, all area with an estimated undiscovered geothermal favorability class less than 10 was also removed because it was determined that the data demand is quite low. The result of these exclusions left 218,575 km² of potential area. Figure 1 shows the breakdown of this area by favorability class. The total area decreases significantly for the favorability of 10 and above.

Figure 2 shows the locations considered to have the highest demand for geothermal exploration. It is clear from this map that favorability of greater than 15 occur in relatively small locations (shown in red on Figure 2).

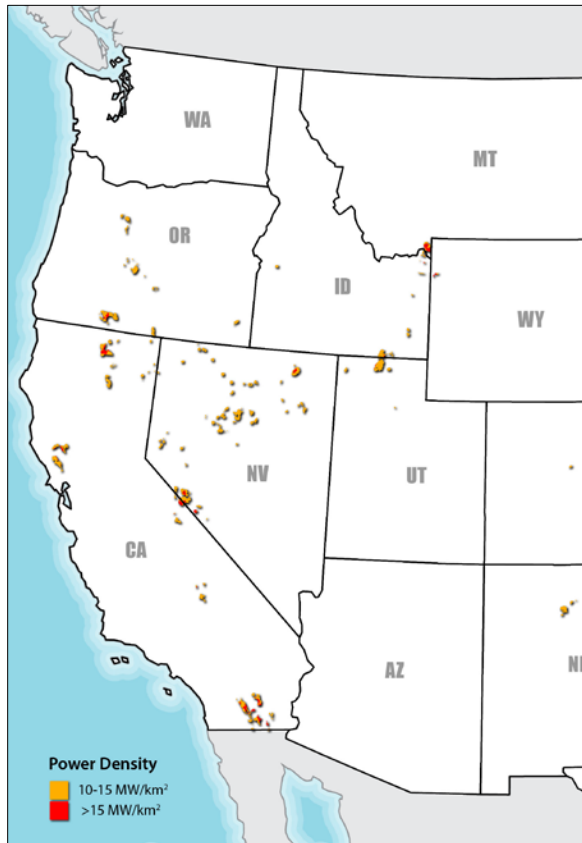


Figure 2: Highest priority areas for exploration.

The majority of the remaining locations are represented by 67 localized sites— potential sites for future GTO data collection efforts. Based on their relative proximity to developing or operating geothermal projects, these sites were separated into two groups: near a project (bordering the 10-km buffer) and not near a project. Thirty-one of the 67 sites were considered near current projects, but due to the exclusions previously mentioned, these sites are at least 10 km away.

DATA AVAILABILITY

After identifying the sites where there is high favorability for hydrothermal resources, the next step was to determine the availability of data, by type, for each of these locations. A comprehensive collection of data coverage for the entire U.S. (but focusing on the western U.S.) was undertaken to assess the

availability of data for each of the five data types previously listed.

Note that for geologic maps, only those with scales less than 1:99,000 were considered for data coverage. Though a general geologic map for the entire United States exists, it may not be very useful for exploring a particular geothermal site.

Eight data availability categories were defined for the purposes of this study.

1. Data available on NGDS, with complete metadata for analysis.
2. Data available on NGDS, but with incomplete/missing metadata for use in the analysis.
3. Data available digitally, are planned to be added to NGDS, but have not yet been added (including moratorium data).
4. Data available digitally, but currently, there are no plans to add them to the NGDS (but could be added).
5. Data available digitally, but currently, there are no plans to add them to the NGDS (data are proprietary and will not be added to NGDS).
6. Data that are available, but not yet in a digital format.
7. Data that are in the process of being collected.
8. Data have not yet been collected.

Data coverage was mapped using six different sources. The four main data sources from which data coverage information was collected were NGDS contributors, the U.S. Geographic Information Network (USGIN), State Geothermal Data, and industry (via phone calls).

- Solicitations for data from the NGDS contributors included: Southern Methodist University, Energy & Geosciences Institute at the University of Utah, Stanford University, Nevada Bureau of Mines and Geology, Oregon Institute of Technology, and the USGS.

Table 2: Data collection summary.

Data Type	Geological Maps	Geochemistry Data	Well Data	Geophysical Data	Fault Maps
Total area with data coverage (km²)	247,100	643,600	2,685,400	74,800	1,844,600
Western states without data collected	None	None	None	New Mexico Washington Wyoming	None
Top three data sources	National Geologic Map Database	Oregon Institute of Technology	Southern Methodist University	Energy & Geoscience Institute	Nevada Bureau of Mines and Geology
	Nevada Bureau of Mines and Geology	USGS	State Geothermal Data	Industry	State Geothermal Data
	State Geothermal Data/USGIN	Nevada Bureau of Mines and Geology	Oregon Institute of Technology	Nevada Bureau of Mines and Geology	USGS

- WFS services⁵ from USGIN and State Geothermal Data with keywords that matched the five data types were loaded into the data coverage map automatically. The data types pulled from State Geothermal Data included active faults, aqueous chemistry, borehole temperature observations, fault maps, geologic maps, heat flow, lithology logs, seismic event hypocenters, thermal conductivity, thermal springs, volcanic vents, and well headers.
- Over 40 industry contacts were solicited for exploration data. In many cases, the industry contact only provided information about current DOE-funded projects or other publically announced projects.

Additionally, data were collected through an online data search for georeferenced data relevant to geothermal exploration.

Finally, to allow for independent users to add data coverage in the future, an online tool was developed and made available through Geothermal Prospector (https://maps.nrel.gov/gt_prospector). This tool allows users to enter their contact name and email address, draw a coverage area on a scalable map of

⁵ Web Feature Service (WFS) is a standard for creating web services that provide access to geospatial datasets. They can be queried either spatially using a location of interest or by providing attribute filters to determine locations meeting certain criteria.

the United States, and provide a data set name, the data set type, and the data availability category. It also allows users to indicate whether data are proprietary and add any comments specific to a data set. Continued use of this online tool by the geothermal industry could aid future data gap analysis efforts, and should be encouraged so that industry can provide feedback on the data gap assessment results provided in this study.

It is important to note that a large portion of the data collected was embedded within a portable document format (PDF) such as a report or conference paper, and was not georeferenced. For this stage in the data gap analysis process, it was not feasible to digitize all these data; however, these records are still available for future data collection efforts.

Table 2 provides a summary of the data collected by data type and the top three data sources for each data type. The data type with the most data coverage is well data, with slightly over 30% of the 88,000 10-by 10-km² grid cells having data available. The data type with the lowest data coverage available is geophysical data. In contrast to the other four data types where data were collected for all of the western states, no geophysical data were collected for New Mexico, Washington, or Wyoming. Geophysical data are known to exist for these three states, but it was either not in digital format (i.e., it was in PDF format) or it was not found through the search of the six data sources.

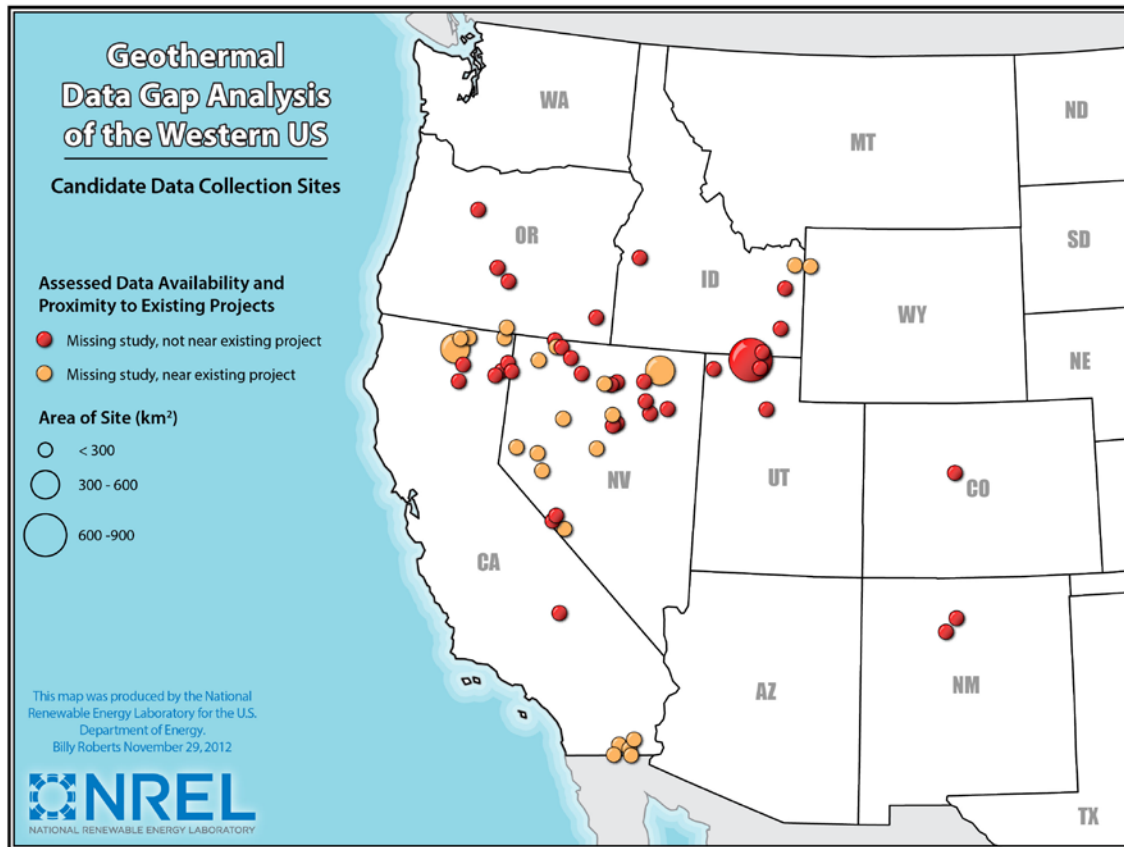


Figure 4: The centroid and the location of the 59 identified candidate sites for exploration gap analysis with their relative surface areas.

DATA GAP ANALYSIS

The final step was to match data availability to data needs in a gap analysis to determine the data available for the 67 individual sites. To accomplish this, the data coverage grid, with its 88,000 grid cells, was intersected with the map of the 67 sites with potential data needs. If more than 5% of the site was covered by a grid cell with data available within the cell, that site was considered to have data coverage. Overlap of a portion of the site area with a data coverage grid cell means that data are available within (at most) 13 km of that portion of the site. It does not necessarily mean that there are data within that site, because the grid cells are, in most cases, much larger than the site area. This analysis was carried out for all of the 67 sites for each of the five data types.

Eight of the 67 sites had coverage from all five data types, demonstrating no gaps in the selected types of data. Therefore, these eight sites were removed from

the final list of data collection sites. The remaining 59 sites are considered the list of candidate sites for potential GTO solicitations for data collection.

Figure 4 shows the location of the centroid of the 59 candidate sites, of which 23 are located near an existing project, and 36 are not. Also shown on the map is the relative area of each site, broken into three groups: less than 300 km², 300-600 km², and 600-900 km². The majority of the sites have surface areas less than 300 km², with two sites with surface areas in the range from 300-600 km², and only one site with a surface area of 812 km² in the range from 600-900 km².

GAP ANALYSIS RESULTS

The number of candidate sites with data gaps varied significantly among the five data types analyzed. Figure 5 shows a summary of the number of sites missing data, by data type, ranked from the data type with the fewest number of sites with gaps on the left

side of the plot to the highest number of sites with gaps on the right side. The results are distinguished by proximity to an existing project. Fault mapping had the most data coverage with only one site missing data. On the other hand, only three of the 59 candidate sites had geophysical data coverage over

more than 5% of the site area. The number of sites missing well data, geological maps, and geochemistry data were very similar, ranging from 16-23 total sites. For all the data types analyzed, sites near existing projects had better data availability than sites farther away.

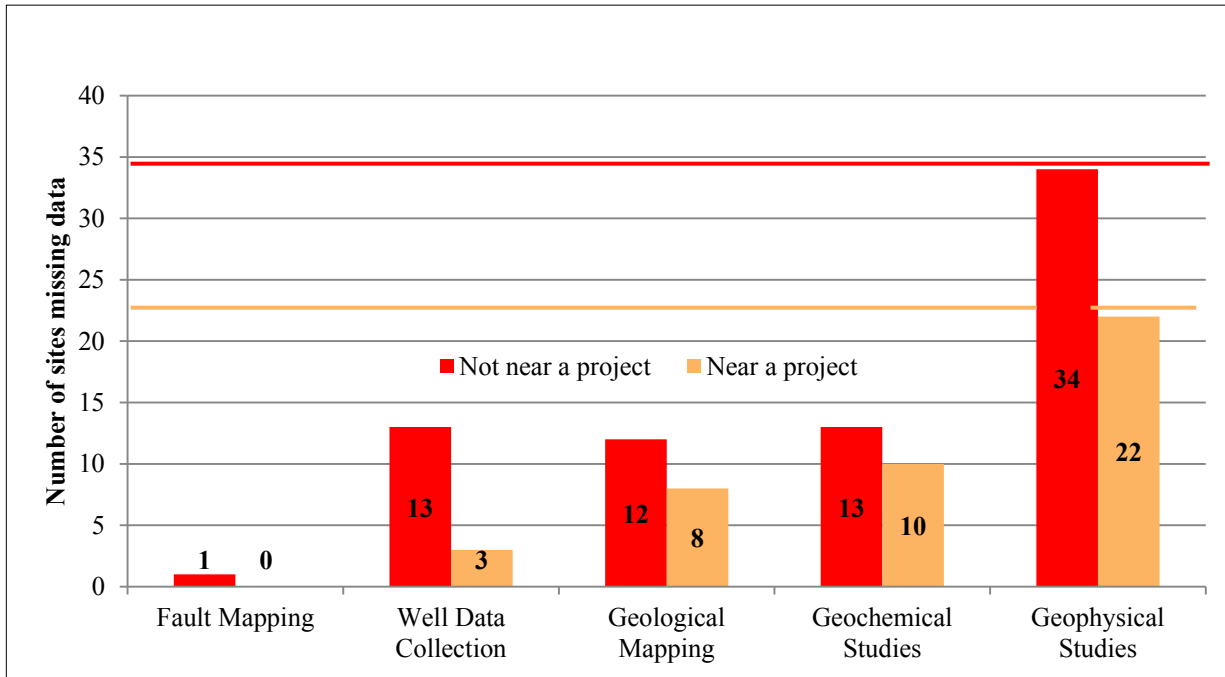


Figure 5: The number of sites missing data for each data type, separated into sites located near and not near an existing project. The solid lines indicate the total number of sites in each group: 36 total sites not near a project and 23 total sites near a project

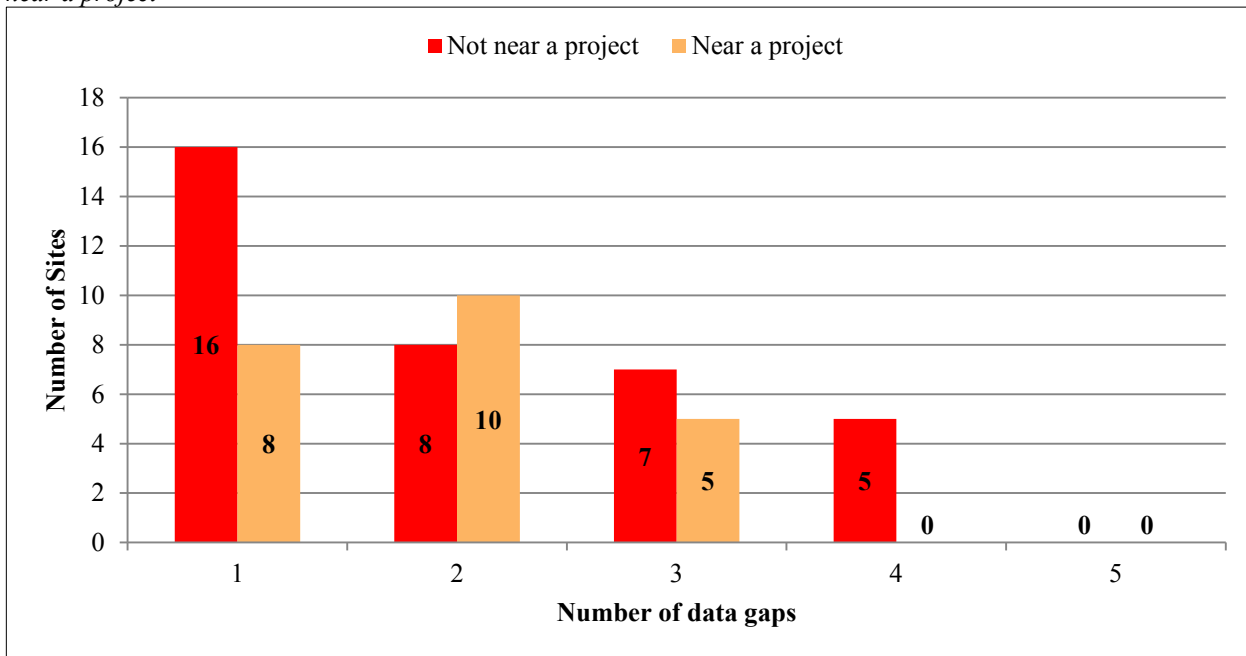


Figure 6: The number of sites with levels of data gaps. Sites with only one data gap are on the left; Sites without any data gaps are on the right.

It is also interesting to look at the concurrence of data types available at the candidate sites. Figure 6 shows the number of sites related to the number of gaps. If four of the five data set types are available at a site, then that site has only one gap. A number of sites, 24 of the 59, are only missing one data type. All of the sites considered near a project have at least two of the five data sets present. Only five sites are missing four of the five data sets. Finally, none of the candidate sites are missing all five of the data types.

Lastly, it is relevant to look at the spatial distribution of the sites with data gaps throughout the western U.S. Figures 7-11 show, for each of the five data types, the 59 candidate sites and: (1) whether a site has the data set available (gray); or (2) if it is missing data, (red) if it is considered not near a project or (orange) if it is near a currently developing or operating geothermal project.

Each site is provided a site name, which is determined from (1) any intersection of the site area with a previously identified geothermal area or (2) the name of the nearest mountain peak. A summary of the data for each site is included at the end of the report in Table 5. This table lists the site name, the latitude and longitude of the center of the site area, the surface area for the site, and the data available at each site for the five data types.

For all data types, it is important to keep in mind that, because of the large size of the grid cells and

(sometimes) potential sites, the overlap of the two areas does not necessarily mean the available data are located in the potential site.

Fault Mapping

All of the 59 candidate sites except for one in northern Nevada have some data coverage of fault maps (Figure 7). The high data coverage for fault maps is likely in part due to the use of faults in the USGS estimate, to identify sites with the highest favorability for undiscovered resources (Williams et al. 2008). Also, mapping of faults was a task that was undertaken by many state geological surveys and the USGS over the past 60 years.

Well Data Collection

Only three sites (two in Nevada and one in Wyoming) of the 26 considered near a current project are missing well data. However, for sites considered not near a current project, 13 of the 36 sites are missing well data. These 13 sites are located in six states, with a large portion of them located in northern Nevada and California (Figure 8). Based on this analysis, collecting more well data could be useful for identifying geothermal resources relatively far away from current operating or developing projects. As previously mentioned, because of the size of the grid cells, a site can be within a grid cell that has well data without the well being within the site.

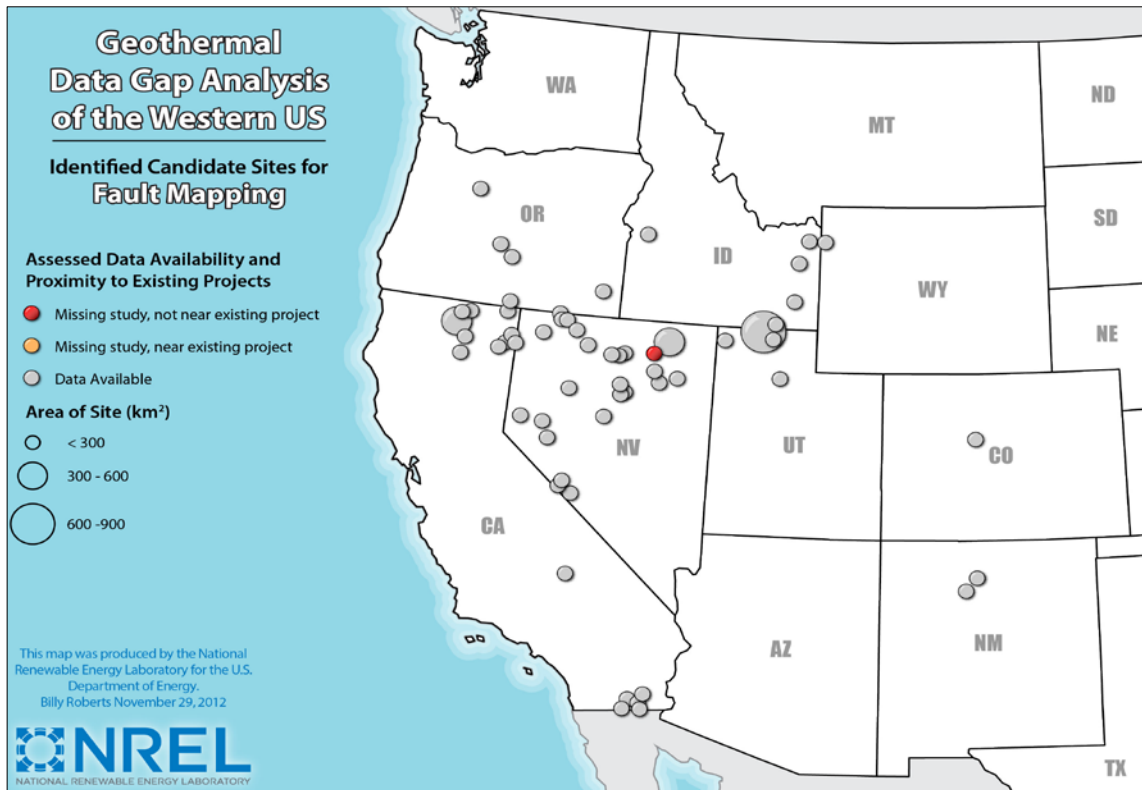


Figure 7: Sites with data gaps for fault mapping

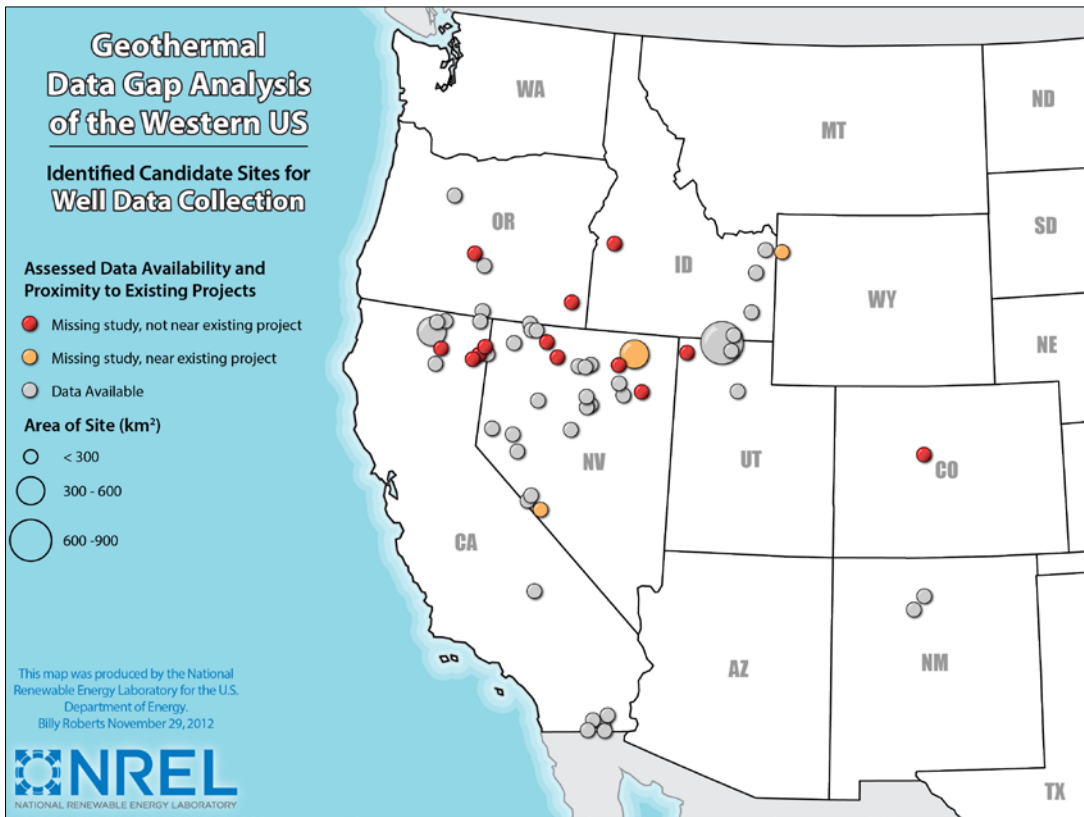


Figure 8: Sites with data gaps for well data collection

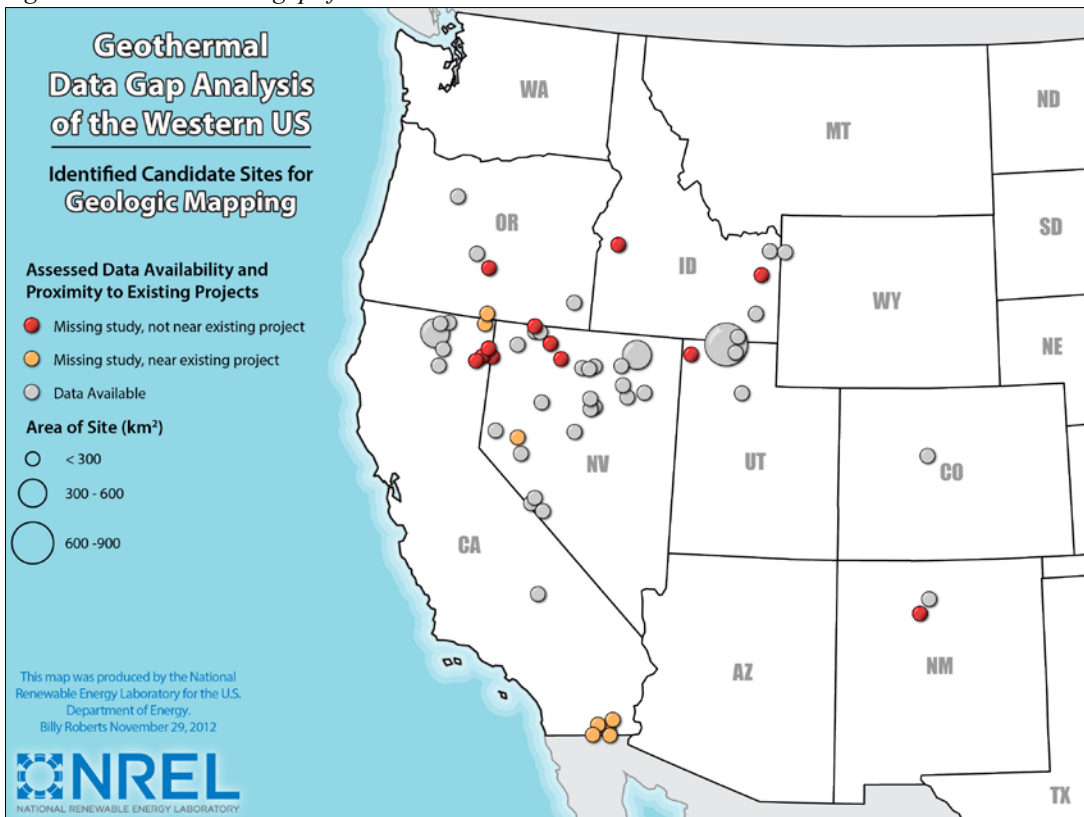


Figure 9: Sites with data gaps for geologic mapping

Geological Mapping

The percentage of sites missing geologic maps is similar between sites near and not near an existing project (Figure 9); about 33% of both sets of sites are missing geological map data. Only geologic maps with scales less than 1:99,000 were included as data coverage. Without this cut off, the entire western U.S. would have geologic map data available because of generalized statewide geologic maps at larger resolutions. Sites missing geologic maps are in seven states, the majority of them in northern Nevada and California.

Geochemical Studies

A comparable number of sites near and not near an existing project are missing geochemistry data (Figure 10). Geochemistry data are often collected from springs as well as from geothermal and oil and gas wells. Of the 16 sites missing well data, 12 of them are also missing geochemistry data. These are spread throughout the western U.S.; however, all of the sites in Utah have geochemistry data coverage

available.

Geophysical Studies

For almost all of the sites, data coverage of geophysical data was not acquired during the data collection efforts (Figure 11). If the geophysical data exist, they were not discovered either because: (1) they were not digitized or (2) they were not made publically available. The only sites where geophysical data coverage was acquired are located close to one another, with one in southern Oregon, one in northwestern Nevada, and one in northeastern California. These three sites also have very small surface areas and are all smaller than 114 km². Based on this analysis, geophysical data represent the largest gap for sites with high potential for undiscovered resources, both near and not near current projects. Collecting more or making previously collected geophysical data more accessible could greatly aid in characterizing highly favorable areas for undiscovered geothermal resources in the western U.S.

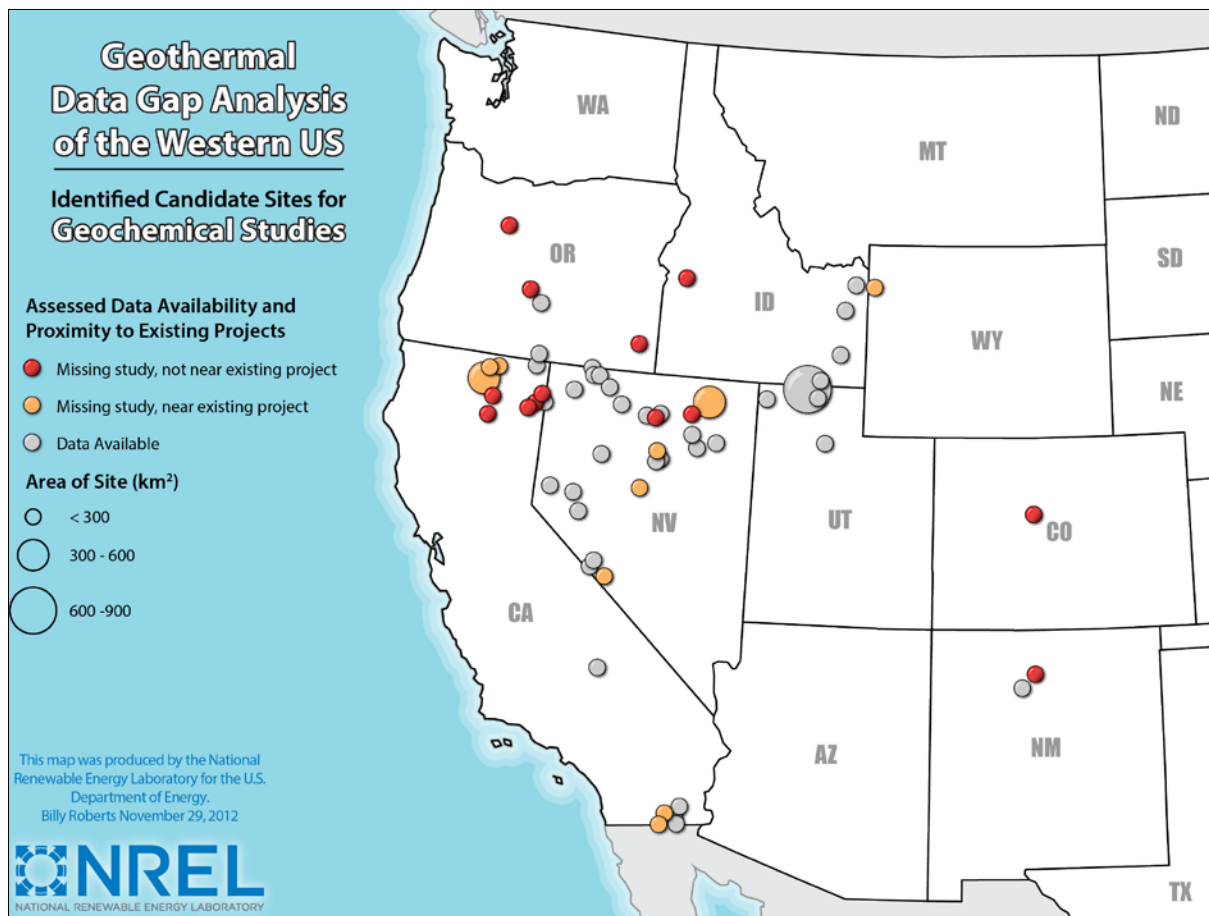


Figure 10: Sites with data gaps for geochemical studies.

CONCLUSIONS

The data types chosen for the gap analysis, including fault maps, geologic maps, well data, geochemical data, and geophysical data represent some of the primary data sets collected on a regional scale for identifying new hydrothermal resource areas. It is known that data exist beyond what was collected for this analysis at the candidate sites, but these data are either not easily accessible or not in a readily available digital form.

There are some data available at each of the candidate sites. This is expected because some information must be available for these sites to be considered highly favorable and to be given a high power density estimate for the USGS undiscovered resource estimate (Williams et al. 2008).

Of the five types of data sets, the one with the smallest amount of data available is geophysical data, with only three of the 59 sites having data coverage acquired as part of the data collection efforts. In comparison, there is very good coverage of fault maps at the 59 candidate sites, with only one site

missing data coverage. There is greater data coverage for sites near a project than those not near an existing project; this is most apparent in the well data coverage.

The data collection efforts for this analysis focused on the major contributors to the NGDS to take advantage of their recent efforts to collect geothermal data and generate metadata. The data gap analysis could be improved by including data that are not currently in a readily available format, such as maps embedded in conference papers and reports. Also, minimizing the size of the grid cells could slightly change the results of the gap analysis and increase data coverage accuracy. Finally, as more users add data to the NGDS, to USGIN, to State Geothermal Data, and to the gap analysis through the online tool developed on Geothermal Prospector, the gap analysis will become more accurate. Future efforts will focus on further automating data uploads from the NGDS contributors as well as incorporating additional contributions.

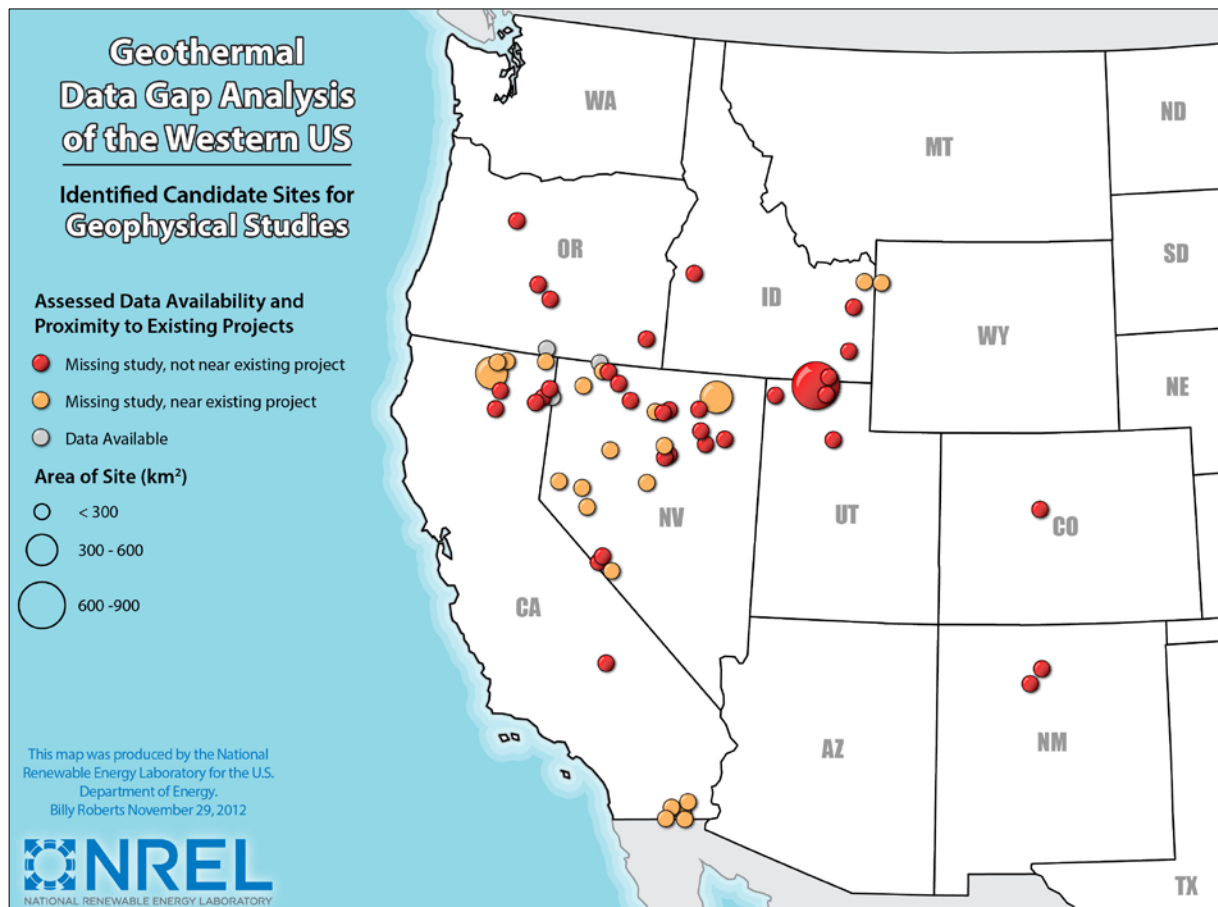


Figure 11: Sites with data gaps for geophysical studies.

REFERENCES

Geothermal Energy Association (GEA). (2012), "Annual US Geothermal Power Production and Development Report."

Orris, G.J. and Bliss, J.D. (2002), "Mines and Mineral Occurrences of Afghanistan," U.S. Geological Survey, Open-File Report 02-110.

U.S. DOE, Office of Energy Efficiency and Renewable Energy. (2011), "Geothermal Technologies Program Blue Ribbon Panel

Recommendations," Sponsored by United States Department of Energy, Office of Energy Efficiency and Renewable Energy.

Williams, C.F., Reed, M.J., Mariner, R.H., DeAngelo, J. and Galanis, S.P. Jr. (2008), "Assessment of the Moderate- and High-Temperature Geothermal Resources of the United States," U.S. Geological Survey Fact Sheet, 2008-3082.

Table 5: Candidate exploration site data.

Site Number	Site Name	State	Latitude	Longitude	Site area (km ²)	Fault Mapping	Geophysical Studies	Geological Mapping	Geochemistry Studies	Well Data Collection
1	Bonita Butte	CA	41.718	-121.683	61.28	Yes	No	Yes	No	Yes
2	Juniper Butte	CA	41.769	-121.422	16.72	Yes	No	Yes	No	Yes
3	Nine Buck Butte	CA	41.480	-121.797	560.56	Yes	No	Yes	No	Yes
4	Brushy Butte	CA	41.139	-121.482	29.38	Yes	No	Yes	No	No
5	Freaner Peak	CA	40.749	-121.541	237.42	Yes	No	Yes	No	Yes
6	Fandango Peak	CA	41.875	-120.331	21.25	Yes	No	No	Yes	Yes
7	Dusenbury Peak	CA	41.322	-120.115	10.92	Yes	No	No	No	No
8	Olson Mountain	CA	40.998	-120.454	51.55	Yes	No	No	No	No
9	Buck Mountain	CA	41.120	-120.274	7.90	Yes	No	No	No	No
10	Mahogany Mountain	CA	41.138	-119.970	24.24	Yes	Yes	No	Yes	Yes
11	Lone Butte-CA	CA	35.774	-117.716	135.86	Yes	No	Yes	Yes	Yes
12	Superstition Mountain	CA	32.901	-115.693	211.84	Yes	No	No	No	Yes
13	East Mesa	CA	33.044	-115.293	55.85	Yes	No	No	Yes	Yes
14	Sunrise Butte	CA	32.658	-115.815	31.80	Yes	No	No	No	Yes
15	Deer Peak-South	CA	32.679	-115.339	24.78	Yes	No	No	Yes	Yes
16	Deer Peak-North	CA	32.825	-115.400	22.06	Yes	No	No	Yes	Yes
17	Strawberry Butte	NV	41.967	-118.758	5.39	Yes	Yes	No	Yes	Yes
18	Fisher Peak	NV	41.823	-118.690	31.80	Yes	No	Yes	Yes	Yes
19	Black Butte	NV	41.826	-118.523	67.73	Yes	No	Yes	Yes	Yes
20	Trough Mountain	NV	41.473	-119.187	37.57	Yes	No	Yes	Yes	Yes
21	Coyote Hills	NV	41.606	-118.203	39.52	Yes	No	No	Yes	No
22	Squaw Peak	NV	41.279	-117.818	52.33	Yes	No	No	Yes	No

Site Number	Site Name	State	Latitude	Longitude	Site Area (km ²)	Fault Mapping	Geophysical Studies	Geological Mapping	Geochemistry Studies	Well Data Collection
23	The Knolls	NV	41.102	-117.089	19.76	Yes	No	Yes	Yes	Yes
24	Sixmile Hill	NV	41.095	-116.874	56.46	Yes	No	Yes	No	Yes
25	Big Butte	NV	41.164	-116.706	52.70	Yes	No	Yes	Yes	Yes
26	Red Hill	NV	41.235	-115.877	20.00	No	No	Yes	No	No
27	Lookout Mountain	NV	41.518	-115.413	300.17	Yes	No	Yes	No	No
28	Adobe Summit	NV	40.789	-115.775	21.85	Yes	No	Yes	Yes	Yes
29	Drown Peak	NV	40.520	-115.608	24.00	Yes	No	Yes	Yes	Yes
30	Lone Butte-NV	NV	40.654	-115.090	142.81	Yes	No	Yes	Yes	No
31	Bald Mountain	NV	40.410	-116.747	71.29	Yes	No	Yes	No	Yes
32	Mount Tenabo	NV	40.231	-116.589	56.75	Yes	No	Yes	Yes	Yes
33	Squaw Butte-NV	NV	40.166	-116.705	45.54	Yes	No	Yes	Yes	Yes
34	Black Knob	NV	40.205	-118.231	7.99	Yes	No	Yes	Yes	Yes
35	Cinder Mountain	NV	39.431	-119.533	111.54	Yes	No	Yes	Yes	Yes
36	The Nipple	NV	39.354	-118.883	45.15	Yes	No	No	Yes	Yes
37	Brown Knob	NV	38.970	-118.684	16.00	Yes	No	Yes	Yes	Yes
38	Telegraph Peak	NV	39.607	-117.129	15.91	Yes	No	Yes	No	Yes
39	Miller Mountain	NV	37.986	-118.119	42.86	Yes	No	Yes	Yes	Yes
40	Pinto Hill	NV	37.854	-118.207	51.96	Yes	No	Yes	Yes	Yes
41	Sheep Mountain	NV	37.701	-117.832	6.60	Yes	No	Yes	No	No
42	Lionshead	OR	44.709	-121.729	179.64	Yes	No	Yes	No	Yes
43	Hogback Butte	OR	43.451	-120.845	6.16	Yes	No	Yes	No	No
44	Juniper Top	OR	43.177	-120.443	46.42	Yes	No	No	Yes	Yes
45	Rogger Peak	OR	42.120	-120.302	113.72	Yes	Yes	No	Yes	Yes
46	Jackies Butte	OR	42.592	-117.551	76.00	Yes	No	Yes	No	No

Site Number	Site Name	State	Latitude	Longitude	Site Area (km2)	Fault Mapping	Geophysical Studies	Geological Mapping	Geochemistry Studies	Well Data Collection
47	Squaw Butte-ID	ID	44.057	-116.363	39.80	Yes	No	No	No	No
48	Snake River Butte	ID	44.119	-111.366	19.43	Yes	No	Yes	Yes	Yes
49	Kelly Mountain	ID	43.579	-111.650	15.69	Yes	No	No	Yes	Yes
50	Steamboat Hill	ID	42.650	-111.736	75.15	Yes	No	Yes	Yes	Yes
51	Red Knoll	ID	42.093	-112.272	41.62	Yes	No	Yes	Yes	Yes
52	Franklin Hill	UT/ ID	41.900	-112.630	812.49	Yes	No	Yes	Yes	Yes
53	Thatcher Mountain	UT	41.725	-112.320	57.62	Yes	No	Yes	Yes	Yes
54	Ingham Peak	UT	41.645	-113.758	43.12	Yes	No	No	Yes	No
55	Round Knoll	UT	40.787	-112.062	8.00	Yes	No	Yes	Yes	Yes
56	Calf Creek Hill	WY	44.108	-110.868	35.68	Yes	No	Yes	No	No
57	Taylor Hill	CO	39.405	-106.308	19.21	Yes	No	Yes	No	No
58	Loma Parda	NM	36.078	-106.319	36.72	Yes	No	Yes	No	Yes
59	Cerro del Pino	NM	35.768	-106.628	23.61	Yes	No	No	Yes	Yes