Geothermal Potential Could be Hot in the Western US

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ABSTRACT

Exploring for good geothermal development sites in the Western US is not simple, even though a lot of the region is in the Pacific "Ring of Fire" where most of the world's geothermal potential is located. The Ring of Fire is really more nearly horseshoe in shape and is the 25,000 mile area that extends from New Zealand, Indonesia, the Philippines, and Japan, turns east through the Aleutian Islands, and then heads south along the coasts of North, Central, and South America. The Ring is home to over 75% of the world's active and dormant volcanoes. There are six Western States that are in or near the Ring, namely Alaska, California, Idaho, Nevada, Oregon, and Washington.

These States may have significant geothermal potential due to the active and dormant volcanoes, which can provide the necessary heat sources to form geothermal reservoirs. These reservoirs have porosity and – with good meteorological conditions – can bring heat to the surface and form what geologists call "surface manifestations". The manifestations include mud pots, fumaroles, and hot springs. However, the six States have significant groundwater at 50 to 2000 feet below the surface that is fed by late winter, spring, and early summer snowmelt. This groundwater is cold and can block potential surface manifestations from occurring.

The Utility Geothermal Working Group, a non-profit organization formed by the Geothermal Resources Council to promote cost-effective geothermal development, plans to work with the US Department of Energy to identify potential sites and geothermal mapping techniques, including Vertical Electric Sounding and Audio Magnetotellurics, to be used in exploration of the sites. This paper describes the plan and the suggested mapping techniques to analyze the formations below the groundwater mask and approximate the location and size of geothermal reservoirs.

Introduction

There is an old story about a geothermal developer that hired a geologist to find potential geothermal reservoirs. Each day started with the developer meeting the geologist, taking off his boots, and sending him out into the field. The day ended when the geologist returned and the developer looked at his feet. If the geologist's feet were burned and blistered, the developer would say, "Tomorrow, go back to where you were today." If his feet were not, the developer would say, "Tomorrow, go somewhere else."

Exploring for potential geothermal development sites is not that simple, but scientist have determined that some of the most promising areas for geologists' bare feet to get blistered are in what is called the Pacific "Ring of Fire". The Ring of Fire is really more nearly horseshoe in shape and is the 25,000 mile area that extends from New Zealand, Indonesia, the Philippines, and Japan, turns east through the Aleutian Islands, and then heads south along the coasts of North, Central, and South America. According to Wikipedia, the Ring is home to over 75% of the world's active and dormant volcanoes. There are six US States that are in or near the Ring, namely Alaska, California, Idaho, Nevada, Oregon, and Washington.

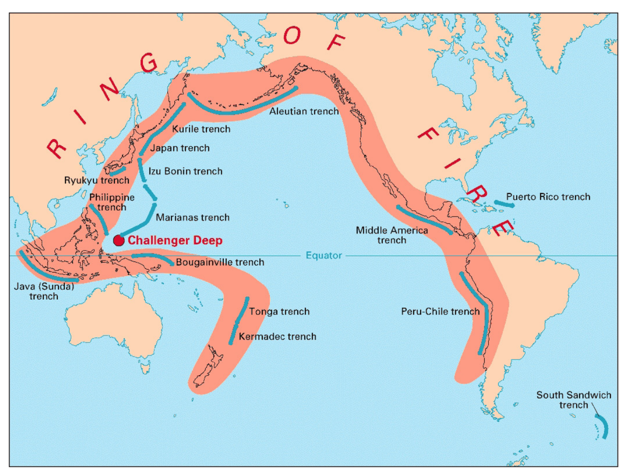

Figure 1. The Pacific Ring of Fire.

These States may have significant geothermal potential due to their active and dormant volcanoes, which can provide the necessary heat sources to form geothermal reservoirs. These reservoirs have porosity and – with good meteorological conditions – can heat to the surface and form what geologists call "surface manifestations". The manifestations include mud pots, fumaroles (vents that emit hot vapors), and hot springs. However, the six States have significant groundwater at 50 to 2000 feet below the surface that is fed by late winter, spring, and early summer snowmelt. This groundwater is cold and can block potential surface manifestations from occurring.

Figure 2. Hot spring is located at the bottom of the picture and a fumarole is in the center.

A good example of the masking effect can be seen in the graph, which shows the temperatures at various depths in a Nevada geothermal exploration well. The cold ground water lowers the temperatures at depths between 50 and 2000 feet. Below that level, temperatures rise to promising levels and the driller of the well was able to intercept a geothermal reservoir.

US Department of Energy's Geothermal Program, Western Area Power Administration, and the Geothermal Resources Council are partnering to conduct a remote sensing webinar that discusses geothermal mapping techniques. As of press time of this paper, the date for the webinar has not been set. These techniques include Vertical Electric Sounding and Audio Magnetotellurics

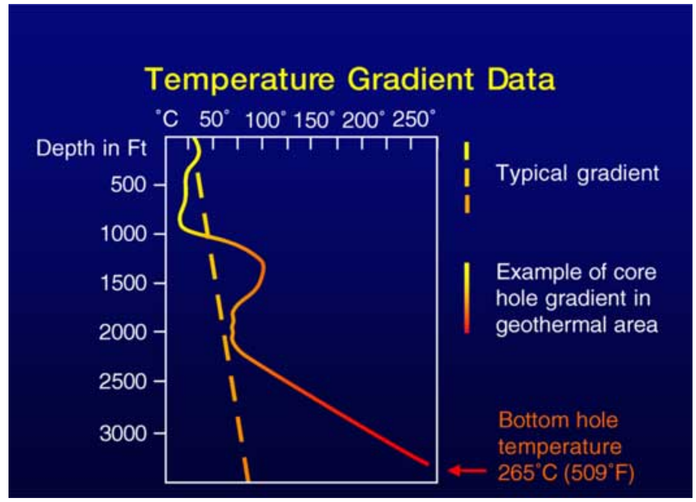

Figure 3. Potential Webinar.

and and other potentially effective methods to find the "hidden treasures" of geothermal reservoirs masked by meteorologic and geologic conditions.

Although not 100% accurate, the mapping techniques presented in the webinar have the capability to analyze the formations below the groundwater mask and approximate the location and size of geothermal reservoirs. Geologists like these methods because they can apply them with their boots on. The webinar will include a discussion of potential sites to conduct up to three exploration activities using the techniques.

Remote Sensing and Mapping Techniques

Seismology, which began with a significant role in the oil and gas industry, has been adapted to geothermal exploration. Seismic waves propagate and interact with subterranean components and respond accordingly. Active seismology relies on using induced/man-made vibrations at or near the surface. Passive seismology uses earthquakes, volcanic eruptions or other tectonic activity as sources.

Gravimetry studies, which can identify granite bodies that are indicators of geothermal potential, use changes in densities to characterize subsurface properties. The studies can also identify subsurface fault lines which can be used as prime drilling locations because their densities are much less than surrounding material. Changes in groundwater levels may also be measured and identified with gravitational methods. This recharge element is imperative in creating productive geothermal systems.

Magnetotellurics (MT) measurements can detect resistivity anomalies associated with productive geothermal structures, including faults and the presence of a cap rock, and allow for estimation of geothermal reservoir temperatures at various depths. Geological materials are generally poor electrical conductors and have a high resistivity. Hydrothermal fluids in the pores and fractures of the earth, however, increase the conductivity of the subsurface material. This change in conductivity is used to map the subsurface geology and estimate the subsurface material composition. Vertical electrical sounding (VES) is very popular in conventional geophysical studies, such as gas, oil, and coal exploration but it is rarely used in geothermal surveys.

Telluric currents are phenomena observed in the Earth's crust and mantle over the past 150 years. The currents are induced by changes in the outer part of the Earth's magnetic field, typically caused by interactions between the solar wind and the ionosphere. Thunderstorms also cause these currents.

Telluric currents flow in the surface layers of the earth. The electric potential on the Earth's surface can be measured at different points, enabling a geothermal exploration team to calculate the magnitudes and directions of the telluric currents and the Earth's conductance. Telluric currents will move between each half of the terrestrial globe at all times. They move equator-ward in the day and pole-ward at night.

The field varies in time and over the frequency range 0.001 to 5 Hz. Electric potential gradients caused by telluric currents range from 0.2 to 1000 volts per meter. At any location, the current density is a direct function of the interhemispheric currents and their potential gradients. Geologist have estimated that telluric currents overall during twelve hours in one hemisphere are in range of 100 to 1000 amperes. The telluric current intensity is sufficient to drive the air movements that create atmospheric electricity.

Telluric and magnetotelluric methods are used for exploring the structure beneath the Earth's surface to geothermal fields, petroleum reservoirs, fault zones, ground water, magma chambers, and plate tectonic boundaries.

Geochemistry is a disipline used in geothermal exploration. It includes relating surface fluid properties and geologic data to geothermal bodies. Temperature, isotopic ratios, elemental ratios, mercury and CO_2 concentrations are all data points under close examination. Geothermometers and other instrumentation are placed around field sites to increase the fidelity of subsurface temperature estimates.

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