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Calculating Formation Heat Reservoir Content In Sedimentary Rock

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When exploration is conducted for an energy resource, the important questions to ask and the answers that are sought include how large is the resource or how much of the resource can be produced? In the hunt for coal shallow coal has been strip mined but deep coal acquisition is done in a different manner that may leave a substantial amount of the resource behind out of necessity. In oil and gas exploration the same questions are considered, which is why secondary and tertiary recovery methods attempt to obtain more of the oil resource. Still, a substantial amount is left behind in the target formation due to various properties of the oil-rock interaction that makes the oil immovable with existing techniques. Heat acquisition for geothermal power production raises additional questions that included the rate of heat production versus heat replenishment.

The questions involving the amount of heat resource for geothermal energy development can have an added uncertainty depending upon the geologic environment that is developed. Geothermal production in an active volcanic area can be considered to be unlimited due to the nature of the heat source being long lived in the region and related to an active tectonic regime. In less active regions, where heat is left over from intrusions, heat production through fault systems that allow water to travel deep into the earth and be heated makes determining the amount of the resource that can be developed difficult if the depth, age, size, temperature, and type of intrusion are uncertain. Heat reservoir approximations can be made if these parameters are known by making educated estimates as to the rate of cooling of the intrusion over time due to natural heat dissipation.

Heat production from sedimentary rocks is different and is more analogous to the development of oil and gas in several ways. Porosity of the rock is important because a water saturated rock will hold more heat than a dry rock. Permeability is important for establishing natural or man-induced pathways for moving hot water from the reservoir to a location where the heat can be extracted. In fact due to the similarity to the oil and gas industry, developing geothermal energy from sedimentary basins can be done with an initial knowledge on the temperature of the reservoir and the volume of the heat resource that is contained within the target reservoir.

Research in BHT data gathering and analysis over a number of years has resulted in the development of a BHT data base of over 8,000 temperature-depth (t-d) readings from oil and gas wells within the Delaware Basin of western Texas (Figure 1). These data cover depths from near surface to around 9 km and thus give a good distribution range of temperatures and their variation with depth. The data was collected on a county by county basis and analyzed in this manner, though an analysis that is tied to various changes in subsurface geology such as major structural changes would be better and is planned for future activity.

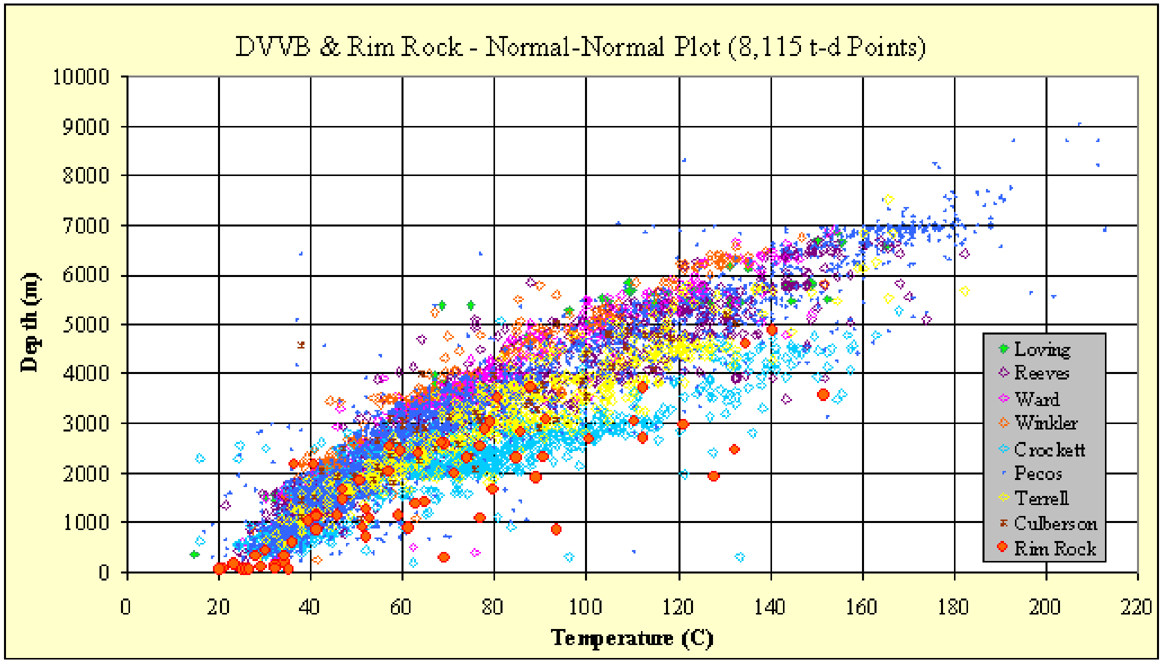

Figure 1. Graph showing BHT data for around 5,000 wells in the Delaware and northern part of the Val Verde Basins. Data is also included in the "Rim Rock" area of the Trans-Pecos volcanic region from wells drilled for oil and gas exploration and from shallow borehole temperature data.

To initiate the study with heat content calculations Reeves County, in the northern part of the Delaware Basin, was chosen as the starting point to initiate this analysis. Latitude and longitude information for some of the wells was previously collected using industry proprietary sources. Additional data was obtained from the Texas Railroad Commission using the GIS public website for cross correlation of well name and survey, block, and section location information to acquire the lat-long information listed on the website. Not all of the wells in the geothermal database had sufficient information to determine lat-long values, resulting in some wells being discarded from this present study. This resulted in around 726 wells being available for analysis. Many other wells within the county, some deep, were not part of the original database. No attempt to include these wells into the geothermal database was done at this time.

Because the BHT well data are from different depths it becomes important to be able to project what temperature might exist at a well location that may not reach the target depth and reservoir for heat extraction. Three methodologies were investigated involving linear and non-linear (logarithmic) projections and using wells with single BHT versus multiple BHT readings per well of which there were 258 wells with multiple readings at different t-d levels. Other types of non-linear functions such as a hyperbolic function were not tested but should be investigated in the future. The result of this analysis was to use a linear fit to only the 258 wells for conducting subsurface temperature mapping at a constant depth and within a target formation.

In addition to the temperature maps that were developed, efforts were made to define the series of equation needed to determine the formation heat content existing in the target formation at the time of production. The volumetric method for determining geothermal energy given by

1) $$E_T = \rho c_p V (T_{prod} - T_{ref})$$

was analyzed and broken down into various components that reflect the specific heat of the rock, the specific heat of the water, and the porosity of the formation.

Variations in water density, that is the brine concentration, alter the heat carrying capacity of the formation water. Additionally the heat capacity of the water varies depending on the temperature of the water. Heat conduction within the water also varies with temperature and density of the water and must be taken into consideration. Finally, sedimentary rocks themselves show an increase in thermal capacity as the temperature of the rock increases.

The volumetric heat energy equation provides a means of determining the amount of heat within a reservoir provided that various reservoir parameters are known. Because we are dealing with sedimentary rocks, many of these parameters can be acquired from sources in the oil and gas industry and from experimental work conducted by various researchers. Some of these parameters, such as the heat capacity of specific target rock strata found within a given basin, have not been determined or have not been made readily available through published articles.

Additional work is still being conducted with this project. Data from the other counties that were part of this study must be included into the maps. Detailed correlation of the temperature data to specific wells and fields is necessary to identify areas of interest for targeted geothermal energy production, not just taking advantage of coproduced hot water for geothermal power generation. Water saturated zones within these wells will need to be identified at the proper temperature for well reentry and fracturing to produce the volumes of hot water necessary for power generation. Finally, a better understanding of heat conduction and advection within sedimentary strata is needed in order to develop a long term sustainable heat production that is in balance with the mechanisms moving heat into these reservoirs over many years of production.

All of these parameters can be determined to provide an initial estimate of the in-place heat content for planning a geothermal exploration program in sedimentary basins. Knowing this in-place heat energy allows for long term planning of production and development of the resource, including optimizing the rate of heat extraction versus heat replenishment for the long term profitability of the project. This type of analysis helps to determine the long term cash flow versus the needed upfront expenses to develop the geothermal target.

Presently several oil and gas companies are looking to develop geothermal energy for on site usages to offset operation expenses in oil and gas production or for utility scale electrical production. These companies, Continental Resources, Pioneer Natural Resources, Denbury Resources, Hilcorp Energy, and Louisiana Geothermal (sister company to Jordan Oil) are spearheading the effort to develop geothermal energy within sedimentary basins for a new and exciting expansion of geothermal energy into the future.