Beyond EOR - Evaluating the Geothermal Potential of Historic Gas and Oil Fields

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Summary

An oil and gas reservoirs life does not have to end when water cuts are high. The vast knowledge obtained from oil and gas reservoirs can be used to understand and calculate additional geothermal potential from historic and near depleted oil and gas fields. By utilizing heat in place calculations, thermal energy can be calculated to understand the thermal energy which resides in the subsurface waiting to be extracted.

In the Western Canadian sedimentary basin, there are plenty of prolific oil and gas reservoirs which are near depletion or have a strong aquifer leg. These oil and gas reservoirs can easilty evaluated for geothermal potential.

A first step to understanding the reservoir potential is to understand temperature of the reservoir. Temperatures can be estimated via wireline logs or well test data and inferred across the area by calculating a geothermal gradient. The geothermal gradient is defined as:

$$Geothermal\ Gradient = \frac{Temperature\ at\ Depth - Surface\ Temperature}{True\ Vertical\ Depth}$$

In oil and gas basins, care must be taken in determining formation temperature. Bottom hole temperatures (BHT) measured from wireline logs are usually lower than actual temperatures due to cooling from drilling mud. Using temperature from pressure data or drill stem test temperatures is a closer approximation to actual reservoir temperature. Applying a variable correction to the bottom hole temperature allows for a modification of BHT to true reservoir temperatures (Figure 1). These increases are typically on the order of 10 to 20%. The lithology of rock changes vertically and laterally within a sedimentary basin, along with the thermal properties of the rocks. When investigating a sedimentary basin on a regional scale, geothermal gradients can be assumed to vertically constant and only changing gradient laterally. Surface temperature is also needed to calculate the geothermal gradient. As Canada has significant seasonal temperature differences, ranging from -30°C to +30°C, the ambient surface temperature is not an appropriate value to use. Instead, it is recommended that an extrapolated value from BHT and True Vertical Depth (TVD) is used to calculate the average temperature below the frost line. In Canada we see the average temperature below the frost line to be estimated around +5°C, shown as the X axis intersection point in Figure 1.

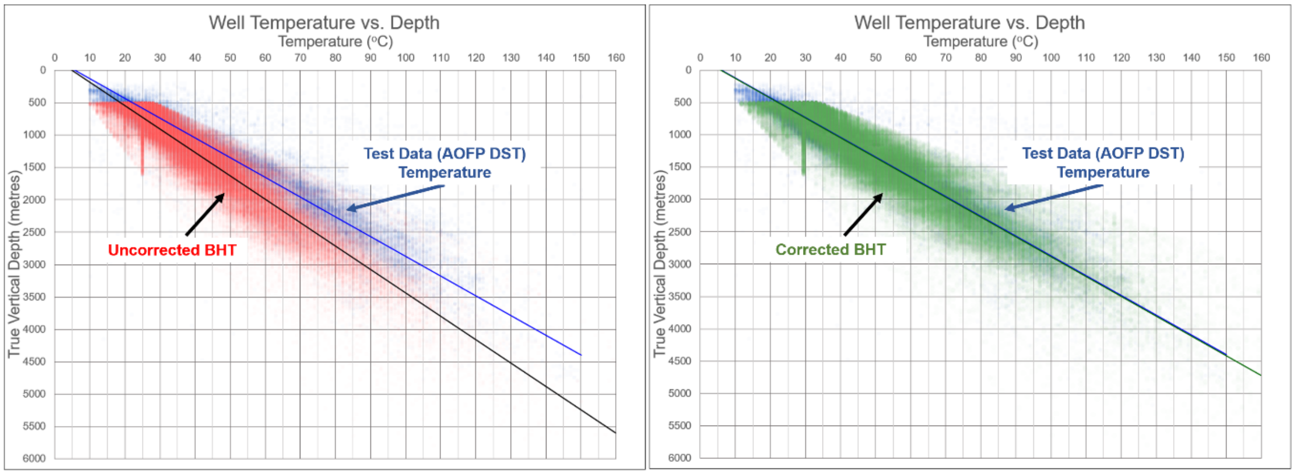

Figure 1: Well BHT vs. True Vertical Depth. The left graph shows the uncorrected BHT in comparison to test data temperatures. The graph on the right has applied a percentage correction which aligns the BHT and test data temperatures. In both graphs, the X intercept of 5 ℃ indicates an average surface temperature below the frost line. These correlations used approximately 370,000 BHT and 50,000 test data temperature points.

The temperature of a particular reservoir can be calculated by multiplying the temperature gradient, or a mapped temperature gradient by the TVD to a particular formation. In Alberta, a very well-known reservoir, the Leduc Formation, is a prime candidate for geothermal due to its large reservoir thickness and relatively high porosities and permeabilities, which in turn will allow for high flow rates. Below (Figure 2) is a map of the inferred temperature at the top of the Leduc formation using corrected wireline logs and mapping of the TVD to the top of Leduc.

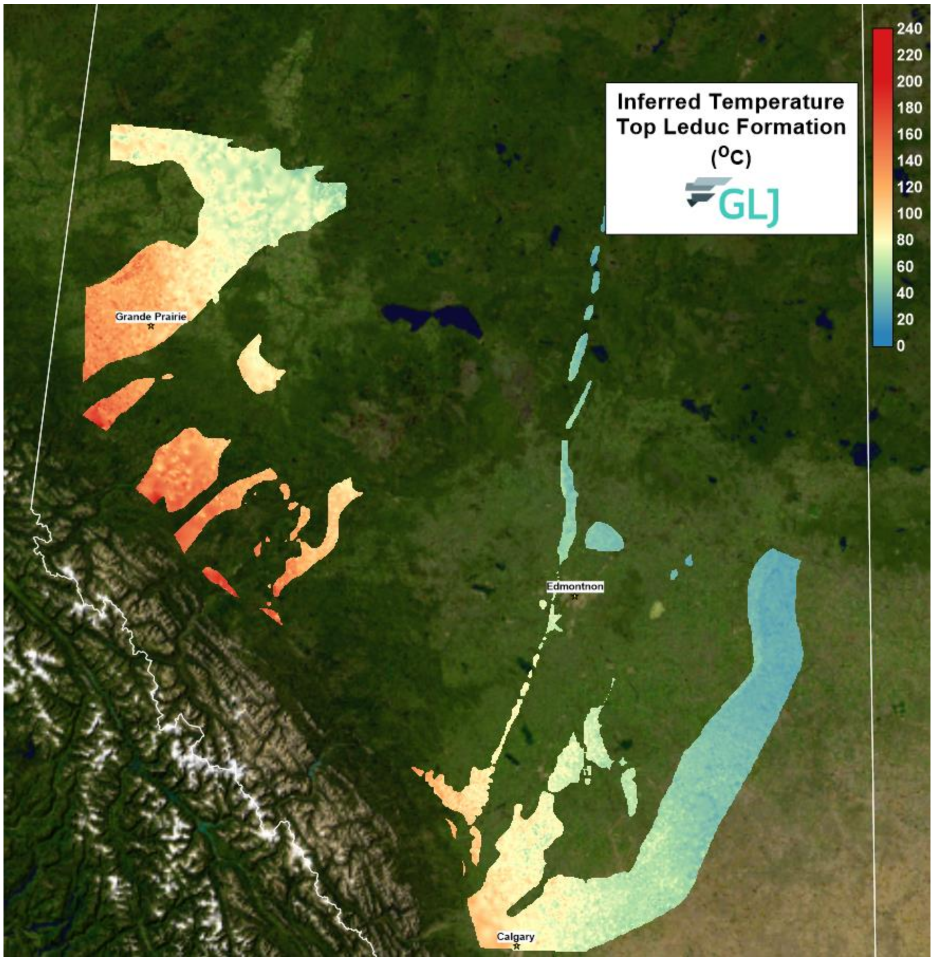

Figure 2: Inferred Temperature at the top of the Leduc Formation. Calculated from wireline temperature data and TVD mapping to the top of the Leduc formation.

Like with oil and gas fields and calculating gas initially in place or oil initially in place, the thermal energy of a reservoir can be calculated. Geological input parameters constitute the basis of the heat in place calculation and is defined by the following:

$$Q_r = \left[(V_n * Cp_r) + \left(V_f * Cp_f\right)\right] * (T_r - T_0)$$

Q_r = Thermal Energy (MJ)
V_n = Net Rock Volume (m^3)
V_f = Net Fluid Volume (m^3)
Cp_r = Specific Heat capacity of the Rock (MJ/m^3K)
Cp_f = Specific Heat capacity of the Fluid (MJ/m^3K)
T_r = Reservoir Temperature (K)
T_0 = Reinjection Temperature (K)

The thermal energy is multiplied by a recovery factor to calculate the amount of energy which will be recovered at the well head and referred to Wellhead Thermal Energy. Recovery factors in hot sedimentary basins range from 10 to 25% (Williams (2007)[1] and can be calculated using the reservoir temperature, minimum facility temperature and reinjection temperature (Lavigne & Maget, 1977)[2]. Electrical Energy can be estimated by multiplying the Wellhead Thermal Energy by a geothermal plant utilization factor. Ranges for gross plant utilization factors depend on the temperature of the reservoir and usually range between 8 and 15% (Retting, A., 2011)[3]. The Electrical energy output in MJ can be divided by the project life, typically 30 to 50 years to estimate the total energy in MW.

In areas currently with high water production, energy can be calculated from the produced water using the density of the fluid, specific heat capacity of the fluid, flow rate and change in temperature of the fluid and is defined by the following:

$$\boldsymbol{H = \rho_f * Cp_f * Q * (T_i - T_0)}$$

H = Heat flow rate (J/s or W)
ρ_f = Fluid density (kg * m^{-3})
Cp_f = Specific heat capacity of the fluid (K * kg^{-1} * K^{-1})
Q = Flow rate of the well (m^{3} * s^{-1})
T_i = Input temperature (K)
T_o = Output temperature (K)

Like with the heat in place calculations, the heat flow rate can be multiplied by a geothermal plant utilization factor to calculate the available electrical energy of the produced water.

Oil and gas fields do not have to be abandoned and forgotten when oil and gas has production has finished. Value in the reservoir may still be present with the thermal energy of the reservoir. This presentation will walk through the workflow of calculating the geothermal potential of a reservoir. It will assess the heat in place of a reservoir, and the subsequent thermal and electrical outputs as well as calculate the thermal and electrical energy from hot water production.

[1] Williams, C.F., (2007). Updated methods for estimating recovery factors for geothermal resources. In: Proceedings, Thirty-Second Workshop on Geothermal Reservoir Engineering. Stanford University, January 22–24, 2007, SGP-TR-183. 7 p.
[2] Lavigne, J.; Maget, P. (1977) Les Ressources Géothermiques Française—Possibilités de Mise en Valeur; Report, 77 SGN 433 GTH; Bureau de Recherches Géologiques et Minières (BRGM): Orléans, France.
[3] Rettig, A (2011) Aus Abwärme wird Strom, Elektrotechnik 6/11, Automation & Elektronik